The · Four · Rocks:

with · Walks · and · Drives

about · New-Haven.

Dana.

ON THE FOUR ROCKS

OF

THE NEW HAVEN REGION,

EAST ROCK, WEST ROCK, PINE ROCK AND MILL ROCK,

IN ILLUSTRATION OF THE FEATURES

OF

NON-VOLCANIC IGNEOUS EJECTIONS.

WITH A GUIDE TO WALKS AND DRIVES ABOUT NEW HAVEN.

BY

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NEW HAVEN:
TUTTLE, MOREHOUSE & TAYLOR, PRINTERS.
1891.

PREFATORY EXPLANATIONS

For New Haven readers and others not versed in Geology.

Of the four grander divisions of geological time, the Archæan is probably represented by the crystalline rocks of the eastern border of the New Haven region; the early Paleozoic, by those of the western border; the Mesozoic, unquestionably, by the Red Sandstone which is the substratum of the whole region; and the Cenozoic, by the superficial river-made deposits of the plain. Accordingly, the Cenozoic beds rest on the Mesozoic Red Sandstone; and the Mesozoic, on crystalline rocks of either Paleozoic or Archæan age. The three periods of Mesozoic time are the Triassic, the Jurassic and the Cretaceous or Chalk period. The Red sandstone, which outcrops about all the ridges and is well exhibited at the East Haven quarries, was made during the later part of the Triassic period and part of the Jurassic, and hence it is called the Jura-Trias sandstone.

New Haven bay is both topographically and geologically the termination of the Connecticut valley. In the period of the Jura-Trias, an estuary, ten to thirty miles wide, extended along the valley to northern Massachusetts; and in this estuary the sandstone was formed, nearly as sand-beds are now formed in a Delaware bay. The sands were made from the decay of granite, gneiss, mica schist, and other related rocks on either side of the estuary; and they were carried into the estuary by the streams of the land. The waters of the estuary are known to have been either fresh or brackish, by the absence from the fossils of remains of marine life. The stone of Portland, Conn., so much used for fine buildings, and that of Longmeadow, Mass., also of great architectural value, are of this formation, as well as the excellent building stone of East Haven.

The population of New England at this period the reader will find described in geological treatises. Large portions of skeletons of Connecticut reptiles well preserved, have recently come

into the possession of Professor Marsh, from the quarries near Hartford.

This sandstone is almost every where in an upturned condition as a result of subterranean movements. The beds, with few exceptions, have consequently an eastward pitch of 15° to 25°. After the upturning had been to a large extent completed in the New Haven region, the eruptions of trap took place from great fissures opened through the sandstone and the underlying rocks of the earth's crust. The lava which then came up and filled the fissures, and in many places outflowed, is the rock we now call trap. Eruptions also took place through the whole length of the Connecticut valley, probably simultaneously with those of New Haven. The trap of the Hanging Hills of Meriden, and of the line of heights reaching to Mt. Tom and Mt. Holyoke in Massachusetts, was ejected in this epoch of New England history.

Trap is essentially identical in composition with the lavas of the Sandwich Islands and with the basalt of the Giant's Causeway. It is the most fusible of the common igneous rocks, as illustrated in the volcanoes of Hawaii. It consists of the minerals pyroxene, a silicate of iron, lime and magnesia, and the fusible feldspar called labradorite, along with some magnetite. The iron-rust color which so frequently covers the surfaces of the trap proceeds from the oxidation of the iron in the pyroxene, and the ordinary decay of trap is largely a consequence of the same process. Another mineral of like constituents with pyroxene, called chrysolite or olivine, occurs in true basalt, and when present it aids in the decay. It has been found sparingly in the trap of Orange, N. J.

The term *laccolith* applied beyond to the outflows of trap is from the Greek for *lake* and *stone*, and alludes, as explained by Professor Gilbert, to the fact that the outflow is a subterranean widening out of the lava-stream ascending a fissure, somewhat as a lake is a widened stream of water.

The sandstone of the Jura-Trias continued to be formed in some parts of the estuary after eruptions of trap had taken place. Evidence of this has been found in the occurrence of stones of trap in the sandstone of Massachusetts, as first made known by Prof. B. K. Emerson of Amherst. Similar evidence has also been observed in East Haven by Prof. W. M. Davis; and more recently by Dr. E. O. Hovey, in the beds east of Saltonstall Lake.

No rocks or relics of the Cretaceous period have been observed in Connecticut. The first of the two eras of Cenozoic time, the Tertiary, is also, as far as known, unrepresented. But the second, the Quaternary, has left its records in the bowlders, scattered stones, and river deposits of all New England. The "Judges' Cave" is one of the bowlders, though now in pieces. The mass, though weighing probably 1000 tons, was transported by the ice of the Glacial era from some point between Mt. Tom and Meriden.

Its companions in travel, many of them between 100 and 500 tons in weight, are scattered all along the western border of the New Haven region and but few elsewhere. The largest, weighing full 1200 tons, lies just below the top of the Woodbridge heights, directly west of the Judges' Cave and hardly a mile and a half distant.

The thickness of the slowly flowing glacier over the New Haven region was at least 1000 feet; for in the southwestern corner of Massachusetts, only 60 miles distant, it was not less than 2500 feet, as proved by the scratches it left on the high summit of the region, Mt. Washington. Moreover, large bowlders of trap and other rocks were carried by the ice from Connecticut to Long Island; and the slope of the upper surface would hardly have been sufficient for this flow of 30 to 40 miles with less than 1000 feet of height in southern Connecticut.

The scratches made about New Haven and elsewhere in the Connecticut valley by the stones in the bottom of the glacier, and also the travelled bowlders, prove that the movement here was in the direction of the valley, or about S. 10° W. to S. 15° W. But over high western Connecticut the same evidence makes the movement S. 30° E. to S. 40° E. The latter was the prevailing course of the glacier also over the Connecticut valley, except for the lower part of the ice lying within the valley; for a valley is like a groove in confining and giving direction to the flowing material within it, whatever the direction above the level of the groove. Consequently, bowlders of granite, gneiss and other rocks from the higher parts of western Connecticut might have passed over the Connecticut valley if they could keep in the upper current. But if large, they would have gradually sunk in the glacier, because of their weight and the many crevasses, until within the southward-flowing bottom ice, and thus be made to join the val-

ley bowlders for the rest of their journey. The New Haven region thus got many a bowlder of granite, gneiss and quartzyte from the west, the "hard-heads" of quartzyte probably coming from Canaan, the gneiss and granite from Seymour and beyond.

Next came the Champlain period or that of the melting of the glacier. The melting of a winter's ice makes now great floods in the spring; then it was the melting of the ice of many centuries of winters. The floods filling the valleys transported the sand and gravel which the ice let loose and made the terraces along the rivers. The waters of West river, Mill river and the Quinnipiac in this way built up and levelled off the New Haven plain. The plain owes its width to their combination in one broad flood before reaching the New Haven Bay: first, the union, south of West Rock, of the waters of West river and Mill river, and, finally, that of all together, south of East Rock. These facts respecting the plain are illustrated on the first two of the accompanying maps.

THE FOUR "ROCKS"

OF THE

NEW HAVEN REGION.*

THE observations on the igneous ejections of the New Haven region here recorded and discussed were mostly completed during the years 1879 and 1880, shortly after the publication (in 1877) of a detailed topographical map of the region by the U. S. Coast and Geodetic Survey, made under the special direction of R. M. Bache. As this map is on the large scale of $\frac{1}{10000}$, or about $6\frac{1}{3}$ inches to the mile, and has 20-foot contour lines, it afforded a very convenient basis for the record of geological facts.

A reduction of a portion of this map to a scale of two miles to the inch, is presented on Plate II† and a general map of the whole New Haven Region, to Mt. Carmel on the north and Saltonstall Ridge and Lake on the west, on Plate I. Except-

* This chapter, on the Eruptive epoch in the geological history of the New Haven region. is republished from the Am. Journal of Science, Vol. XLII, August, 1891.

† This map is a portion of Plate II in the writer's paper on the "Phenomena of the Glacial and Champlain Periods about the mouth of the Connecticut Valley, or the New Haven Region" published in the American Journal of Science, xxvii, 113, Feb. 1884). The limit of the New Haven plain is marked by a dotted line at the base of the hills, and the contour-lines over it are omitted, the heights instead being given after a special survey. The small nearly circular depressions marked on the map represent "Kettle-holes." The New Haven plain was of river-flood origin and it is presented on the map with the outlines and height unaltered by the gradings for road-making, and by the making of mill-dams; and hence the map is a map of the region of New Haven before 1640, as stated in its title.

ing the hills in the southwestern corner of the map making Plate II, its whole area, even that of the New Haven plain, is underlaid by the Jura-Trias Red-sandstone formation. (The excepted hills are part of the border of metamorphic schists that bounds the Jura-Trias region on the west.) The map shows the positions of the four trap ridges—more strictly trap-and-sandstone ridges—West Rock, Pine Rock, Mill Rock and East Rock, and gives their heights above mean tide. These rampart-like elevations are now two to three miles from New Haven Bay; but they bear evidence of having been for a time the headlands of a much larger bay.

The ridges are part of the Jura-Trias Mountain-range of the Connecticut Valley. (1) East Rock and West Rock are like the other north-and-south ridges of the range in their form, structure and direction, and West Rock ridge after a course of seventeen miles, dies out just where the higher trap ridges of the Mt. Tom line commence, showing an interlocking with the rest of the system. (2) They consist of Jura-Trias sandstone with an intercalated sheet of trap (as the igneous rock is popularly called). (3) The sheet of trap in the ridges has a rising inclination westward, or a dip eastward, like the associated beds of sandstone, the liquid rock having been extruded from a fissure or fissures situated somewhere to the eastward. (4) As a consequence of these common features, denudation by water and ice has given to the New Haven ridges the features typical of the range,* namely, a steep western front, consisting of sandstone below and the harder trap above, a top of bare trap, and eastern slopes of sandstone, that is of the overlying sandstone.

From such common features the inference as to a common method of origin is natural. Still, as Professor Davis claims, it needs also other support for acceptance.

We note also (4) that these Rocks are situated at the southern extremity of the Jura-Trias Mountain-range; for the Con-

* In the writer's paper on the Geology of the New Haven region of 1869, (Transactions of the Connecticut Academy of Sciences, ii, 1, 1870), he observes that "the sandstone mass with its intersecting dikes of trap constituted the block out of which the future New Haven region was to be carved by various denuding agencies."

necticut Valley and its Jura-Trias beds do not extend over Long Island. Instead of this, Long Island pertains to an east-and-west system of mountain-structure. Whether nearness in position to this east-and-west range has occasioned any of the features of the Rocks is an interesting question for consideration.

1. Summary of the principal facts and conclusions.

The facts.—The facts relate to the sandstone of the New Haven region as well as the trap; for the sandstone was broken through to give exit to the liquid trap. and it broke as such a sandstone would break.

(1) The sandstone, as the rock is comprehensively called, varies from fine-grained to coarse, and beyond this, to a fine and coarse conglomerate, even cobble-stone-gravel conglomerate. When fine-grained and shaly it is not a firm laminated rock, but divides or crumbles readily to thin chips. The more massive kinds are usually traversed with fractures; and none has much firmness except where consolidated by heat from the trap-ejections, or the hot vapors produced thereby. Consequently, fissures made though the formation should have great irregularities, from irregular fracturing and the tumbling into them of masses of sandstone and large sections of their walls.

(2) The thickness of the sandstone intersected by the fissures over the center of the New Haven region was at least 3000 feet, as proved by borings at a point half way between the bay and the west end of Mill Rock. Along the West Rock line the depth was probably less, as this ridge is within a mile and a half of the western metamorphic limit of the Connecticut Valley of Triassic time. Beneath the sandstone the fissures came up through underlying crystalline rocks, in which they would probably have great regularity in course, width and continuity.

(3) When the heat from the trap, or the hot vapors generated by it, consolidated the sandstone, it generally made hard, durable rock of the coarser kind, but left the finer beds, alternating with the coarse, fragile and chip-making; and this

was so, apparently, because hot vapor penetrates most easily the coarser beds for the cementing work. The heat, through the penetrating vapors, generally discharged more or less completely the color of the beds it consolidated, producing an ash-gray and brownish shade; made in them steam tubes with blanched walls; produced blotches of impure chlorite, or epidote, and crystallizations of hematite and epidote, and less commonly garnet. But the finer beds that alternate with the coarse commonly retain, except perhaps for a few inches, their red color, and even have it deepened to a dark purplish red—as if by the reduction of some of the red coloring matter (oxide of iron) to magnetite. Moreover, the sandstone often loses all the old bedding. These varying effects from the heat have added much to the original irregularities of the beds.

(1) Of the four Rocks, East and West belong to the prevailing north-and-south system, as already stated; the other two, Pine Rock and Mill Rock, to a transverse system.

(2) In East Rock and West Rock the sheet of trap made by outflow from the opened fissure or fissures has a length westward of 100 to 500 yards.

(3) The supply fissure, or its filling, the dike, descends beneath the eastern slope with a large eastward pitch: the angle of pitch in the case of East Rock being about 50°.

(4) In Pine Rock and Mill Rock, the trap is in *dikes*, there being no evidence of any outflow. Yet these dikes have in some of the outlets the great breadth of 150 to 300 or more feet.

(5) The pitch of these dikes is to the northward; and its angle 18° to 40°—both characters of unusual interest.

(6) Although neither East Rock, Mill Rock nor Pine Rock has a length exceeding a mile and a half, each has three or four distinct outlets of trap, separated by intervening sandstone; moreover, there is wide diversity between the Rocks in the form and arrangement of these areas of extruded trap, as the map illustrates.

(7) The trap of the several ridges, according to examinations by E. S. Dana, is true doleryte, free, or nearly so, from chlorite

and other evidences of interior alteration, and not at all vesicular.

(8) Columnar fractures give the rock a rudely columnar structure, in which the half-defined columns are four to eight feet in diameter. In the west fronts of the north and south ridges the rude columns have usually an inclination nearly at right angles to the mean dip of the associated sandstone—according thus with the usual rule: perpendicular to the cooling surfaces. But among the columnar fractures, whatever the inclination of the columns, that plane of fracture or joint which is transverse to the sides of the dike or trap-mass and nearly vertical is the most strongly developed, and consequently the trap often cleaves into nearly vertical plates or laminæ of great extent, much like a laminated rock. There usually is also a second easy cleavage-direction, nearly at right angles to the former so that rectangular columns sometimes come out with great prominence.

(9) The outflows of trap have a floor either of an inclined layer of the sandstone or of edges of the upturned layers.

The principal conclusions.—(1) The igneous eruptions of the New Haven region took place after the sandstone had been upturned; that is, after the evolution of the Connecticut-valley mountain-range in this part of the valley had made great progress.

(2) None of them were volcanic eruptions, for there was no center of action, no pericentric discharge of volcanic materials.

(3) In the outflows from the fissures (those of East and West Rock) the liquid trap did not escape into the open air and spread over the surface, but entered between layers of the sandstone.

(4) Moreover the flow was not by gravity into spaces that had been previously made, but a forced flow that opened spaces or chambers for its occupation, the liquid rock thus lifting the overlying sandstone as long as the discharge was continued. By such means the sheets of liquid trap attained, in some cases, a thickness of 300 or more feet. This forcible

opening and filling of a chamber in the sandstone by the upthrust lavas, is a *laccolithic* process, it according with that of the typical laccoliths ably studied out and described by Gilbert.*

(5) The intrusion of the flowing rock between the sandstone layers took place at comparatively shallow depths, where the pressure of the rock was not too great to prevent it.

(6) It was favored, in each case, by the fact that the oblique fissure supplying the lava was inclined in the same direction with the layers of the uplifted sandstone—both inclining westward, the dip being eastward.

(7) The termination of a fissure in several outlets, exemplified in three of the Rocks, was largely due to the great inclination and depth of the fissures opened through the weak upturned and faulted sandstone, and thence to great downfalls of the hanging wall. The same cause led to irregularities in the width and forms of dikes, and influenced the outlines and surface-features of outflows.

(8) The course and dip of supply-fissures was not determined by the foliation or bedding of the schists underneath the sandstone.

2. Special facts from the several Rocks illustrating the above conclusions.

The ridges, Pine Rock and Mill Rock, containing simple dikes are first considered, and then East Rock and West Rock, which include dikes and outflows from them.†

1. PINE ROCK.

The general form of Pine Rock is shown on Plate II, and still better on the following larger map.‡ It is only three-

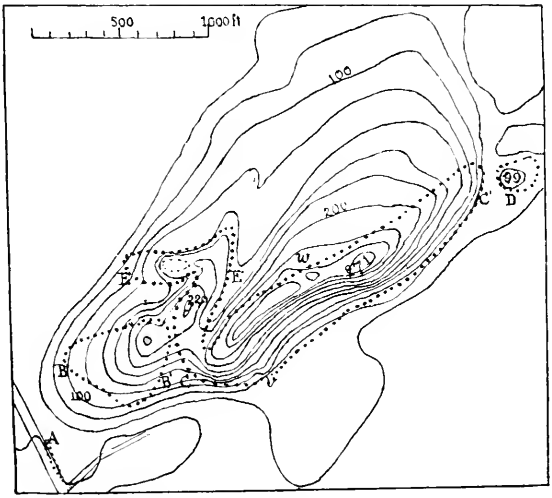
* Geology of the Henry Mountains by G. K. Gilbert, 4to, 1877.

† In justice to Percival, the author of the Report on the Geology of Connecticut of 1842, it should be here stated that there is scarcely an outlet or area of trap mentioned beyond which is not recorded on his map or described in his Report.

‡ The 20-foot contour lines on this map, and also those on that of Mill Rock on page 11, are copied from the Bache Coast Survey map

fourths of a mile long and trends N. 67° E., or east-northeast. This small ridge has three, perhaps four, independent outlets of trap, A, BB′, CC′ and D. The first, at the west end, is a small dike 15 to 20 feet wide, trending north 20° west, and traceable for 220 feet. It dips eastward 25°, and thus proves

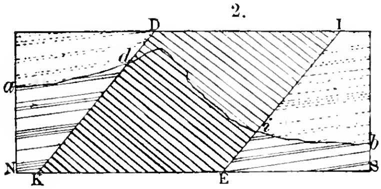
1.



Map of Pine Rock. Heights reckoned from high-tide level. Areas of trap with dotted outline.

that it is not an outlier of West Rock, but part of the Pine Rock group. The other three are, more evidently, outlets from one great fissure. The width of the larger mass, CC′, is about

2.



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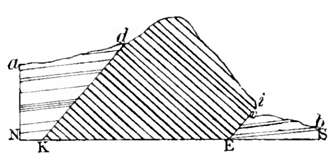


300 feet; and it is therefore one of the widest of dikes. The dip of the dike is 50° to 55° northwestward. This inclined

position (35° to 40° from a vertical) is given the dike in fig. 2, in which D I K E represents a section of it between its sandstone walls before denudation, and *d i* K E, the same through the highest point of the Rock as it now is—or was before recent quarrying. The cross-lining gives the direction of the columnar fractures. The other figure, fig. 3, is a section through *v* on the map, where the removal of the sandstone of the southern wall (*c*, in the section) has left a depression called the *Cave.* (The sandstone of these sections is now concealed by the debris, and outside of this by the Terrace formation.)

The southern wall of the dike is the roof of the cave; the rock has the fine texture and fissured surface usual where it cooled in contact with the sandstone. Just above the cave,

4.

Inclined columns of Pine Rock, above the "Cave."

where the exterior is removed, the surface is made up of the ends of rude columns. A profile view of these inclined columns from a point just south is shown in fig. 4.*

At *w*, (see the preceding map) the *north* wall of the inclined

* From a photograph by G. N. Lawson, of the class at Yale of 1890; taken in December, 1890.

dike is uncovered for a height of 50 feet, the sandstone having been carried off by the glacier.*

At the eastern extremity of Pine Pock (near C′), the trap of the north wall may be seen in contact with hard-baked sandstone. In the large quarry just south, the rock exhibits finely the transverse lamination crossing the dike—referred to on page 4. The laminæ incline 10° to 15° to the eastward, the dip being 80 to 85° to the westward. The surfaces of the plates are usually yellowish-brown with limonite for scores of feet from the summit, owing to the waters that penetrate from the surface downward and oxydize the iron of the rock; but in the transverse joints or cracks, which are less accessible to the waters, there is usually a coating of stilbite and sometimes of other zeolites, as chabazite, analcite, heulandite.† The dike has a few transverse courses of fracture containing prehnite and occasionally apophyllite, but no longitudinal have been observed.

A sandstone ridge connects A and BB′, in which the rock is hard, and has the strike N. 40°–45° E., and the dip 45° S., becoming N. 30° E. and 30° to 35° in dip more to the west. It is mostly a coarse sandstone; but some layers contain stones 4 to 5 inches in diameter.

Origin of the Features of the Rock.

The existence of so many outlets of trap in the small space, and the irregular forms of the areas are unusual facts. BB′ is short, broad and blunt, shield-shaped; and CC′, is duck-like in shape, the irregular bosses at the northwest end (EE′) making the neck and head. These bosses are not in the line of the dike, and must be due to a local catastrophe. In view of the great inclination of the fissure, and its depth of 2000 to 3000

* The shaping of the northern slopes of the Pine Rock ridge is a part of the same work of the ice; and the trend of the mass, like that of Sachem's Ridge. (Plate II), indicates the direction of movement of the glacier. The same is true for the northern slopes of Whitney Peak and Indian Head.

† The surface of the crust of zeolites is frequently tinged with the red iron oxide—which is a probable indication of heat as high at least as 200° F. during the formation of the minerals.

2

feet in the weak sandstone, a caving in of some part of its northern or hanging wall would be of extreme probability. Such a catastrophe would account for the stoppage of the outflow and the separation thus of BB′ and CC′; and such a stoppage of the up-thrust lavas would explain their escape by one or more extemporized outlets, and for the actual position of the apertures on the *north* side of the fissure; and thereby for the making of the bosses. The obstructed lavas of the fissure may also have found exit in the western dike, A.

The trap-mass D is possibly a result of a second smaller catastrophe of like character; but its separation from CC′, may be a result of erosion.

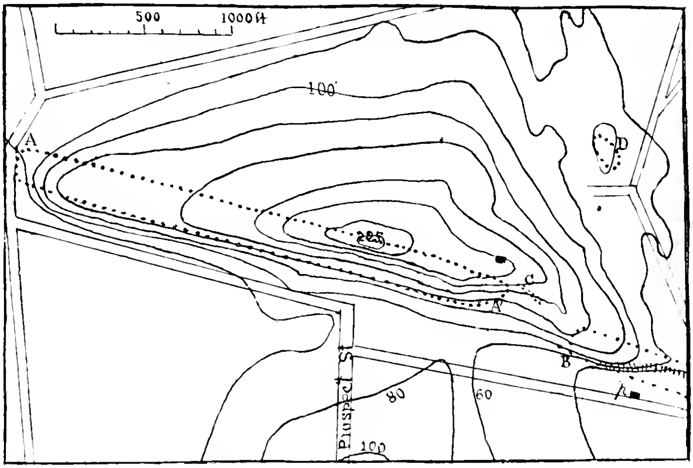
Another consequence of the great inclination of the fissure is the exposure of the dike of heavy trap to degradation through the removal of the supporting sandstone on the south side. Such undermining has produced the steepness of the southern front. And sea-shore *waves* or breakers were probably the chief agent—the shores being those of the broad center, or a central arm, of the New Haven Bay.

2. MILL ROCK AND THE WHITNEY RIDGE.

Mill Rock is one mile distant from the east end of Pine Rock. Its length to Whitneyville or Mill River, is four-fifths of a mile. This small area, as is seen on Plate II, and better in the following larger map, has four independent outlets of trap—the western, AA′, the eastern, BB′; north of the gap between these, a short narrow dike C, and farther north, the isolated area, D. The width of the first, AA′, (as measured at its west end) is 200 feet; of the second, 140 or 150 feet; of the third, 1 to 10 feet; of the fourth, 50 feet, the length being 150. The mass BB′ continues to Mill River where the surface of the country declines to tide level. But the trap does not stop here; it crosses the river and extends on eastward, with an increased width, 180 feet, to the summit of Whitney Peak. The Whitney Peak dike belongs therefore to the Mill Rock region, although topographically part of the East Rock area. The trend of the Whitney Peak portion is S. 68° E.; of AA′,

S. 78° E. The mean course for the whole series to the summit of Whitney Peak is about S. 72° E.

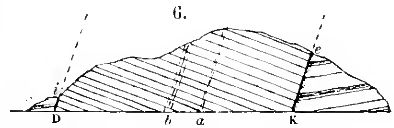
5.



Map of Mill Rock, excepting its eastern extremity. Trap areas with dotted outlines.

The dip or pitch of the main dike is about 72° to the northward, or 18° from the vertical. This inclination and the course of the columnar fractures are well exhibited at the west end of the dike, A, and are represented in figure 6.

6.



Section of Mill Rock, west end.

Besides the columnar fractures at right angles to the walls, there are also longitudinal fractures in interrupted lines, parallel to the walls. Two are seen at the west end of the Rock and are indicated in the above figure. They are now mineral veins. The more southern one, *a*, contains chiefly prehnite, with traces of copper ore, and the trap along its course is solid or little altered. The other is situated about half way between the sides. It contains abundantly the very hydrous mineral laumontite and the trap along it is decomposed; it contains also impure chlorite,

and is fragile for a breadth of six to ten inches. A similar laumontite vein, but nearer the north wall of the dike, is seen at Whitneyville, and also in the trap of Whitney Peak.

The junction of the Whitney Peak part of the dike with BB′ takes place in the bed of the stream at Whitneyville, and is not now exposed to view owing to the dam and the buildings below it.*

The level of the trap beneath the dam is but a few feet above and below tide level. The height of the Whitney Peak dike increases eastward; first by a sudden rise of 100 feet, and then more gradually in the last 500 yards to 280 feet. Whitney Peak has a bold front to the eastward with sandstone at its base showing a sudden stoppage of the fissure in that direction; and at the same place it widens southward—not by overflow, as the precipitous eastward front and the depth of the trap shows, but through the opening of a transverse fissure. The Rock has a steep wall 70 to 80 feet high, on the north side of the summit for nearly 100 yards; but this is due to the removal of the sandstone by glacier action, exposing the north wall of the trap dike.

The narrow dike C is about 110 feet long. It is situated in the face of a bluff of sandstone; and from the evidences of heat in the hardness of the rock, its mottled and light gray color in places, its steam tubes, and epidote, it is plain that the ejection determined the resisting power of the sandstone against denuding agencies. The following figures represent two cross sections from the western half, and a map of the last 40 feet of the eastern half. At 65 feet the outflow is divided, a narrow stream of trap (fig. 9), coming out above a layer of the sandstone 5 to 6 feet thick, the main part of the dike appear-

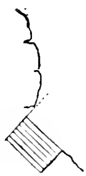
* To the fact of this continuation I have recent testimony from Mr. Eli Whitney, who has superintended the constructions made there during the past forty years. Besides mentioning that the dam was built along the junction of the trap and sandstone, he says that below the dam for some distance, there is trap rock only, no sandstone outcropping there to his knowledge.

The gun factory at Whitneyville was established there by his father, the inventor of the cotton-gin, in 1798, for the manufacture of muskets for the United States Army.

ing below. This envelope of sandstone by trap continues for 30 feet, when the two parts come together again. The depth at which the side stream goes off from the main dike is not known. The inclination of the dike is mostly 25° to 28° (fig. 7) from a vertical, but at 45 feet from the west end it becomes 40° (fig. 8), and 10 feet beyond this, 30°.

7.

8.



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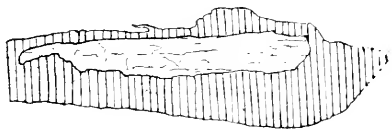


The sandstone of the Mill Rock region is of all degrees of coarseness up to cobble-stone conglomerate; and no distinction is observable between that of the west and east ends.

Origin of the Mill Rock features.

The subdivision of the trap into its four masses may be explained in the same way as that in the Pine Rock area. A downfall of the northern sandstone wall of the fissure, the hanging wall, would account for the separation of AA′ and BB′. Further, the obstruction thus occasioned to the great ascending stream—its width 150 to 200 feet—would have forced open passages to the surface for the discharge of the liquid trap, and thus may have been produced the small dike C, situated near the fissure wall, and the remoter mass D. The irregularities of the little dike C, and the situation of both C and D to the north of the line of the dike, accord with this idea of a downfall of a part of the northern wall. The liability to such a catastrophe in a wall made of the rude sandstone 3000 feet or more high, and having a large inclination, was augmented in both Pine Rock and Mill Rock by the tilted position and faulted state of the sandstone. The beds had already received their eastward dip of 15° to 25°, and breaks and faults innumerable that had been made in the

adjustment to the new tilted position; it was therefore a tottlish structure overhanging a profound abyss. The fact here introduced that the eastward pitch of the sandstone was given it before the ejection of the trap is sustained by facts reported beyond. But an argument for it is afforded here: for if this *eastward* pitch were of subsequent origin, then the Whitney Peak end of the system should be the lowest. Instead of this it is greatly the highest; the ridge slopes westward.

It is possible that the fissures of AA′ and BB′ were, from the first, independent fissures to a considerable depth; for they are not in precisely the same line. If this were so, the above explanation, while in the chief points right, would require some modification.

As in Pine Rock, so with Mill Rock but to a less degree, the northward pitch of the dike made it easy of degradation by sea-shore action. Through such means, beyond doubt, the part of it extending from Mill River westward for 300 yards, was reduced to a width above ground of 40 to 50 feet. This narrowing commences just west of the Pumping House of the City Water Works (*p*, fig. 5), and continues without interruption to the river. It is part of the evidence of a greater New Haven Bay at some former time.

Why the range falls gradually to so low a level at Whitneyville, appears to be explained only on the view that less trap here came to the surface. I have elsewhere shown that it cannot be due to glacial removal. Neither is it probable that fluvial or marine waters have produced it. We have to attribute it to some condition existing or produced in the supply fissures of eastern Mill Rock and Whitney Peak, at the time they were opened.

Besides the dikes of Pine Rock and Mill Rock, there is another transverse dike of special interest which intersects the West Rock ridge just below the margin of Wintergreen Lake, or about one and a quarter miles north of the southern termination of the ridge and four miles from New Haven Bay. It descends the eastern slope of West Rock in an interrupted ridge, forms part of the

southern bank of Wintergreen Lake, sinks to the level of the West Rock surface at the summit, but stands out like a buttress along the steep west front of the Rock. From the last feature I have called it for the past twenty years, the "Buttress dike." It extends south-westward through the metamorphic region of the towns of Woodbridge and Orange to the mouth of the Housatonic—as long since mapped and described by Percival. This dike has a pitch northward, amounting to 25° from a vertical in the part of it intersecting West Rock, but in that through the metamorphic rocks it is nearly vertical.* The strike of the inclined columns in the buttress portion is S. 30–32° E. It is an example of a dike made subsequently to the cooling of another dike, that of West Rock. It has great importance in this connection, since it brings into the Jura-Trias system of mountain-movements a dike intersecting the metamorphic rocks outside of the Connecticut Valley, and one that branches off from the southern or New Haven part of the system.

3. THE EAST ROCK SERIES.

The form of the East Rock area and its position between Mill River and the Quinnipiac, are shown on Plate II. Through denudation by the sea, rivers and ice, it has lost all of the sandstone formation that may have covered the summit, and for the most part that over its slopes above the 200-foot contour-line. The form of its upper portion is therefore largely that of the trap in its constitution—the hard rock that was most successful in resisting wear. This fact gives special interest to the larger and more detailed topographical map making Plate III, as will appear beyond.†

* The rock of the dike is sparsely porphyritic; and the feldspar distributed through it in crystals a fourth to a third of an inch long is anorthite, as shown by G. W. Hawes (American Journal of Science, III, ix, 188, 1875). This character makes it easy to identify the several parts of the dike; it is the only case in which this mineral has thus far been found in the Connecticut Valley trap.

Percival's account of the Buttress dike and its extension southwestward is on page 399 of his Report.

† The map of East Rock Park which is the basis of Plate III, was obtained from the Engineer department in New Haven, through the City Engineer, Mr. A. B. Hill. The roads of the Park from the termination of Orange St., around by

To the north is Whitney Peak, which has already been described as the eastern extremity of the Mill Rock series. South of this and of a large area of sandstone, are East Rock and Indian Head, one in trap surface, but in fact the result of two independent outflows. To the south of Indian Head is Snake Rock, which also has its large trap mass, but is peculiar in having ridges of hard-baked sandstone that are higher than those of trap. The East Rock areas of trap here referred to are lettered on the map BB′, CC′C″, DD′. Besides these there is a more northern one, lettered AA′, which lies near the eastern foot of Whitney Peak.

The trap-mass AA′.—This northernmost mass, is about one hundred yards long. At its northern end it is only forty feet distant from the trap of Whitney Peak, and it is a question, therefore, whether it is not a part of the latter dike. But it is separated from it by outcropping sandstone, except where the interval is narrowest, and at this point there was until recently drained, a standing pool of water, a pretty good indication that sandstone exists beneath, since trap is commonly too much fissured to hold water or afford springs. Moreover, the mass AA′ has the trend of the East Rock series; and,

the north to the summit of East Rock are lettered *F*, and the others *E*. These letters refer to two citizens of New Haven, Henry Farnam and James E. English, who liberally bore the expense of their construction. The topography is in part from the Bache Coast Survey map; but the accuracy of its contour lines was not sufficient for their transfer to the Park map. The heights are reckoned from high tide. The map is indebted to Prof. S. E. Barney, for the determination by leveling of the height of the highest point of East Rock, just south of the monument (358½ feet) and also of other points on its south and east sides, and for that of the junction of the trap and sandstone on the west front near Orange St. bridge (155 feet). The height of the bolt at the Coast Survey Station he found to be 343 feet, and the height of the top of the first step leading to the terrace about the monument, 355 feet. (Prof. Barney's figures are underscored on the map). The circuit road about the summit has a height of 320 to 350 feet; and the nearly parallel road on the east rises from about 216 feet near the quarries south of the summit, to 270 near the junction of the "Farnam drive" and "English drive," and thence declines northward to about 250 where it bends westward. The letters S on the map indicate an outcrop of sandstone in the vicinity of junctions with the trap.

In giving the topography of the Rock, the quarry excavations on the south side above a level of 216 feet are not introduced, it seeming best to represent the Rock in its original form. They are separately mapped on the plate, at *Q*.

besides, ledges of trap along the east side appear to indicate that the supply of liquid rock was from the eastward, like that of East Rock. On this view it is the northern mass of the East Rock series.

East Rock proper.—The trap mass BB′, or East Rock, curves around from N. 25° E., on the north to N. 75° W. at the southwest extremity. Adding to it the Indian Head mass, it ends in an east-and-west dike, and is a complete crescent in outline. It has a bold columnar front, in which the columns incline about 22° from a vertical—the position, being, as is usual, at right angles to the mean dip of the tilted sandstone. A view of the southwest front of the Rock is presented on Plate IV. Plate V illustrates the character and inclined position of the columns, and shows the contrast in the latter respect with Pine Rock.

The upper 200 feet are of trap. The junction of the columnar trap with the sandstone is exposed to view at several points along the front. One such exposure may be seen when crossing the Orange Street bridge. The view in Plate IV, in which the bridge appears in the foreground, has the exposure half way up the front to the right. The height of the junction plane above mean tide at this place is 155 feet. Another is faintly indicated on the same plate directly below the Refreshment House; the height of the junction is there 150 feet. In other exposures of the junction-plane to the north, the height is less and becomes only 85 feet near the Rock Lane bridge; and it is also less to the south being but 132½ feet at B′, the southwest angle of the trap mass. Since the strike of the sandstone of the region is about N. 30° W., the sandstone (or the junction plane) has its greatest height, 155 feet, where the front has this direction; and the bedding of the sandstone in the section for this reason appears to be horizontal. The diminished height to the northward is owing mainly to the exposures being at a lower level on the junction-plane because of the changed direction of the front, it becoming N. 10° E. near Rock Lane bridge. Through this interval the trap retains

its thickness of about 200 feet. North of Rock Lane bridge the underlying sandstone is wholly covered by debris, so that the position of the junction-plane is doubtful.

The supply of the trap forming East Rock came up, as the slope of its surface shows, from the eastward; and it continues rising westward to the western and southwestern margin of the summit. The slope from the summit eastward and northward is gradual for about 300 yards, and then it pitches off at an angle of 45° to 50′ along the course of one of its dikes.

The position of the dike, and thereby of the supply-fissure, is well exhibited at *bc*. A bare wall of trap, 50 to 55 feet in height, descends at the angle mentioned. Since the surface there exposed became solidified against the northern sandstone wall of the fissure, the rock is of fine-grained texture and has an irregularly rifted aspect. The foot of the wall is about 200 feet above high tide, and from it the land, underlaid by sandstone, slopes off gently to the eastward. Since the direction of this wall of trap is S. 15° W., or that of the movement of the ice over this region in the Glacial era, the wall escaped the tearing action of the glacier, and so retains its original surface.

Farther south, along a line from *d* to *e*, there is a similarly steep slope, but it is made of displaced blocks of trap. At its base there is a flat, terrace-like surface, which is near 200 feet above tide level. This steep slope appears hence to have been the course of the wall of another part of the supply-fissure. The flat terrace, although nearly 100 feet wide, is without stones over its surface of either trap or sandstone except in its southern portion, and there occur sandstone in fragments along with trap, and an outcrop of sandstone over trap at S. This fact and the occurrence of a perennial spring in this southern part (at the point toward which the two paths on the map, Plate III, descend) make it probable that the terrace rests on sandstone, and that this sandstone was that bounding on the east, the supply-fissure above referred to.

But there is trap again to the east of this terrace, showing that the lower eastern slopes were supplied from a more

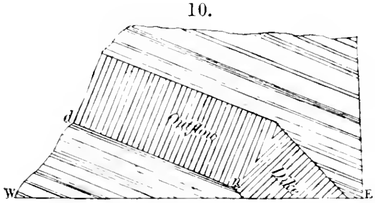
eastern fissure. Along from *c* to *d*, the trap of the outer fissure appears to have flowed over and coalesced with that of the inner. Again south of *e*, the distinction of the two fissures cannot be made out. But the fact that the supply-fissures, one or both had a large inclination—not far from 45°—is evident from the very steep slope of the surface.

Sections of the dikes of trap are nowhere exposed, and hence we are ignorant of the width of the supply-fissures. Judging from those of Mill Rock and Pine Rock, it may have been 150, 200 or 300 feet; but it was possibly much less.

The Outflows.—In East Rock, the trap which overlies the sandstone along the front, was that of outflows from the fissures westward between layers of the tilted sandstone. The fact that the columns of trap have a position at right angles nearly to the inclined layers of sandstone is believed to be good evidence of this intrusion of the melted trap.

Fig. 10 represents the view that has ordinarily been held with regard to the relative positions of the trap and sandstone.

10.



Ideal Section of East Rock before the removal of the sandstone from the summit.

According to it the trap left the dike to flow westward between sandstone layers having a dip of 20° to 25°. A space was opened between the layers of sandstone which the liquid trap filled. It is plain that this chamber could not have been so opened in advance of the inflow; for the hanging wall of the weak sandstone inclined 65° would have had no support. It is hence evident that the ascending stream of trap, forced along its course, opened a way between the layers; that a tongue of trap first entered, which would have been partly cooled against the cold rock; but the flow was kept up below

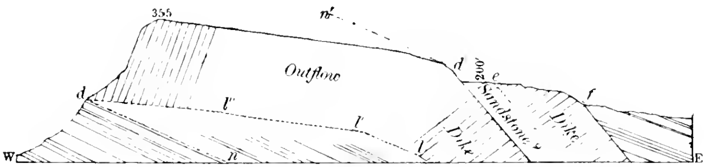
this first intruding portion until the trap had all entered, the lifting of the overlying sandstone going on as it needed more space. This lifting would have brought a strain on the sandstone that would have broken the connection between the lifted portion and that either side, to the northward, westward and southwestward. To the question, therefore, how far did the trap flow westward, the conditions reply: to the wall of such a fracture; and it may not have extended many rods beyond the present limit. The sandstone of the western wall has disappeared in the general denudation over the New Haven region, excepting a small part at the southwest angle, where a zigzag path (Z, Plate III) ascends to its top; the height of this sandstone is 185 feet, which is twenty-five feet above the base of the trap where highest to the northward, and fifty feet above that just south at A′. The locality of this sandstone and the zigzag path is seen on the right margin of Plate IV. The sandstone of the northern wall remains to a height of 196 feet at *m*: the sandstone between Whitney Peak and East Rock is what is left of it. The dip of this sandstone at *m*, near the junction, is 30°, in the direction N. 73° E.; and the inclination of the columns of the trap just above is also 30°.

The theoretical section of East Rock in fig. 10 represents correctly the fact of the intrusion of the melted trap between sandstone layers. But since the bottom over which the flow took place is concealed from view, it is not quite certain that the sandstone layer on which the flow began continued to be the floor to its western limit. Moreover, there is a large discrepancy between the pitch of the trap over the summit and that in the section. An actual section of the rock from east to west (or more exactly E.S.E. to W.S.W. since this is approximately the direction of a transverse diameter) drawn to a scale, fig. 11, throws some light on these points.

This section is essentially right in its profile, but more or less doubtful in its interior lines. The height of the upper surface of the outflow where it left the dike at *d′* is 265 to 270 feet. It was not less than this; for we have this height for

the top of the bare, unabraded wall of trap (adding the part of it under the Summer House west of the road). The length of the overflow to the present western front, is, as already stated, about 300 yards. The height of the western brow of trap in the section is 355 feet;* and that of the bottom of the trap in the western front, 155 feet. These are facts; and the divergence here from figure 10 is very great. Further, the mean angle of the trap surface over the summit is 10° instead of 22°, the mean dip of the sandstone. The latter dip is shown in the lines *dn*; and if the floor had originally this pitch throughout, the thickness of the trap would have been about 450 feet, this being the distance on the scale of the section between *dn* and *d'n'*, while actually it is only 200 to 210 feet.

11.



Section of East Rock, showing the correct profile.

The question arises: How was the lower slope of 10° attained, and how the lessened thickness. Are they a result of wear by glacial or other methods; or was the present slope approximately the original slope of the outflow? A large amount of observation over trap ridges leads me to believe that the loss over East and West Rocks by abrasion has been small, probably not over 50 feet. The glacier, as it was shoved along, might easily have torn off columns from the front, but it would have made little impression on the exposed surfaces. Moreover glacial abrasion would hardly have left the highest points of the summit so near the western edge.

If the outline of the summit approaches that of the original outflow, then—*d* being the lower limit of the trap on the front

* This is the height 80 feet north of the Summit Refreshment House, just west of the road, this being the highest point over this northern half of the summit area.

—a line drawn from *d* nearly parallel to the summit plane, would probably represent the position of the bottom of the outflow. The line *d l'' l' l* has been drawn on this view. It supposes that the trap, on leaving the dike, passed between two layers of sandstone from *l* to *l'* and that afterward it broke away the layer beneath it and flowed on, either over the edges or surfaces of layers as the conditions favored.

The only spot where a section of the floor or plane of junction of trap and sandstone, is seen, is at A', the south-southwest corner of the trap-mass, by the road-side. There, for a few yards, the trap *rests on upturned ledges* of sandstone, and not on one continuous layer. The section is too short for any reliable conclusion were it not sustained by facts from West Rock.

The section, fig. 11, also represents the *inner* and *outer* dikes described above, with the intervening (?) sandstone. The doubts with regard to the widths of these dikes and the area of sandstone have already been the subject of remark.

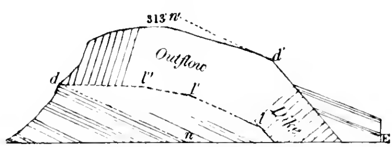
Columns stand out boldly on the steep western front of East Rock. But they have none of the normal forms, for the angle between the most prominent faces frequently approaches a right angle, resulting from a combination of the plane of fracture at right angles to the trap-mass and another transverse. The direction of these planes varies along the course of the Rock on account of the curve in its outlines. At the quarry, on the south side of the summit, at the termination of the zigzag path Z, there is a fine display of broad surfaces in the two directions meeting nearly at a right angle. The courses here are about N. 35° E. and N. 55° W. The surface of one of them for many square yards is covered with rosettes of garnets and scattered minute crystals of magnetite, their faces brilliant in the sunshine. Along the whole western front of the Rock there is a remarkable predominance of planes conforming to its plane through all its changes of direction. This is apparent on Plate IV. and some of the right angles are seen on Plate V.

The upper half of the columnar front (see Plate IV), down to a level of about 220 feet above tide-level, has columns four to eight feet in diameter; below this the size is in general half less; and for the lower twenty feet above the sandstone, they are quite small.

Indian Head.—Indian Head is much like a small edition of East Rock. The length of the outflow is 100 yards; the height 310 feet (313 above mean tide). A section made on the same principle with fig. 11 of East Rock is given in fig. 12.

Indian Head stands quite apart from East Rock. The gap now separating them, where highest, is about 200 feet above high tide, and therefore nearly 160 feet below the top of East Rock and 110 below that of Indian Head, and probably sandstone intervened for the greater part of this depth; for the two Rocks face one another with steep slopes, as well brought out on the map, Plate III. These continue to be

12.



Section of Indian Head.

steep to the very foot of each, where they approach one another down the eastern slopes. Their bases are here in independent valleys, designated on the map by the letters E and I, separated by a low trap ridge, R, so that East Rock and Indian Head, although the trap extends over the surface of the gap from one to the other, are nowhere united at base. The eastward sloping valley, I, lying at the northeast foot of Indian Head is continued in a westward sloping valley I′, at its northwestern foot, and the two together define its outline. The low trap ridge R, between E and I, although consisting at surface mostly of blocks of trap, has a solid ledge in its lower part. It probably crosses the gap westward; and the Summer House,

near 201 on Plate III, may be on its western part. The valley E, at the southeast foot of East Rock, is perhaps, a result of glacial action; but why there should be two valleys side-by-side if erosion made either, is not explained.

The trap of Indian Head rises from the bottom of the small valley just mentioned apparently in two half-separated streams instead of one even stream; but this feature may be a result of erosion. The eastern outline of the trap (see Plate III) is in a line with the eastern of the East Rock trap, indicating that the supply-fissure corresponded in direction with the outer and not the inner of the East Rock courses of fissures. The two Rocks, although alike in features, are to a large degree independent. Abrasion helped to deepen the gap between them, but more by the removal of sandstone than of trap.

Indian Head is peculiar in having a long eastward projection from the southern end. It is described on a following page.

The mode of origin of the trap-masses of East Rock and Indian Head—by a forced flow of lava, opening through its uplifting action, a chamber in the sandstone for its accommodation—entitles the two to be called *laccoliths.* Through degradation, stripping them of the covering of sandstone, they stand side-by-side—a pair of laccoliths.

Snake Rock.—In Snake Rock, a broad mass of trap measuring about 900 by 450 feet in its two diameters lies encased in sandstone. The greatest height of the trap is but 160 feet, and that of the sandstone west of it over 200 feet. The trap covers the eastern slope of the Rock nearly to its foot, thus showing that the supply-fissure was on that side, as in other parts of the East Rock series, and also indicating by its steepness that the fissure was much inclined. At the south end of the Rock, in the yard behind the north corner of the Bassermann house, at a junction of the trap and sandstone, the dip is about 45°; and this is direct evidence as to the inclination.

The area of trap of Snake Rock has on the north the width of that of Indian Head: and the mass may hence owe its increased width northward to an outflow. If so, Snake Rock

contains a half-emerged laccolith, its summit exposed, but the western wall of sandstone still standing and overtopping the trap. The sandstone shows everywhere the effects of hot vapors in all their varied forms, and before encroachments were made by a brewery there was a fine display of columnar sandstone in the southwestern bluff.

Origin of the breaks in the East Rock series.

The prominent breaks in the East Rock series are that between Indian Head and Snake Rock, and that separating the small northern area, AA′, from the main East Rock mass, BB′.

The Indian Head and Snake Rock masses, CC′ and DD′, approach one another bluntly within a hundred yards, and the area of sandstone between has parallel sides, as the map, Plate III, shows. In view of the steep pitch of the supply-fissure, a catastrophe to the western or overhanging wall is a most probable explanation of the break between them. The checking of so great a stream for a length of 100 yards might be expected to open escape-ways in some direction. The long eastern tail-like projection from Indian Head, C′C″, is the result of outflow along an east-and-west fissure. The pitch of the fissure, as the position of the trap shows, was about 25° to the northward. Its southern front is steep and rocky, the northern, gentle and grass-covered. It may be that this supply fissure was the escape-way then made, and the trap the part of the stream that would have occupied the interval had no such catastrophe occurred.

The relations of the northern trap-mass of the series, AA′, to BB′ are doubtful. Yet it is probable that the trap of AA′ was ejected from the north end of one of the two East Rock fissures, or lines of fissures. The ledge of very hard sandstone which extends southward from near the south end of AA′, passes by the east side of the dike-wall *bc*; and it probably derived its position and its excessive consolidation and lost bedding to a catastrophe that closed the fissure for the interval between them, which is only 200 feet wide, yet left it giving out heat, and generating volumes of hot vapors for the consolidating work.

The East Rock masses of trap may therefore be traced to two ranges of fissures. The western was the probable source of the most northern area, AA, and of the summit portion of that of BB′ on East Rock. The eastern, contributed to the lower slopes of East Rock; and also through its continuation southward gave origin to the trap of Indian Head and Snake Rock. But for the accident to the hanging wall of the great fissure, the trap of Indian Head and Snake Rock would have made one continuous mass, and the columnar front of the former might have been continued over part of the present Snake Rock area. The areas of trap in the East Rock series narrow both to the south and the north.

4. WEST ROCK.

The facts and conclusions relating to the West Rock region derive prominent interest from their pertaining to one of the long trap-ranges of the Connecticut Valley region. The area is represented on the accompanying map, Plate VI, from a survey made by the author with chain and hand-level in 1879 and 1880. The 20-foot contour-lines of the steep western and southern fronts of the Rock and the geographical positions are from Bache's Coast Survey map; but the other contour-lines exhibiting the surface features, which required for mapping detailed measurements, are those of the author.*

Features.—(1.) While the general course of the West Rock Range is north-and-south, the western foot of the blunt southern extremity bends round to an eastward course, and ends with north 30° east. The summit of the ridge also curves, in its last 500 yards, around to S. 70° E. or nearly to east-by-west. Its height in this part is 399 to 405 feet above high tide, the geodetic station at the extremity being 399 feet. The eastern foot of the ridge has no corresponding bend.

(2.) The trap of the Rock is a continued mass instead of being divided into several masses through a multiplication of

* The dotted line on Plate II is the north limit of the map, Plate VI. Heights *C* to *Oa* are plane-table results of Prof. H. A. Newton, from Bache's 399 as base.

outlets. But it has a large bay of sandstone, of triangular outline, in its southeastern portion, which from its form is called the Triangle. (3.) South of the Triangle there is a prolonged hook-like point making the southeast termination of the trap.

(4.) North of the Triangle commences the tıap of the west slope of the mountain. For a distance of 500 feet near the foot, increasing to 800 feet above, the surface of the trap is here elevated sixty to eighty feet or more above the level farther north. Moreover it is raised into rounded ridges, and some of these ridges have a high inclined wall on the south side. The first of these walls adjoins the Triangle and has a height of seventy-five feet, a slope of about 45° and an even flat surface free from marks of abrasion. Another similar wall farther north is thirty feet high. The smaller troughs are mostly one to three yards deep. The angle of slope in the embossed surface between the 300-foot and 100-foot contour-lines is less than 17°; and in the surface north of it less than 14°. (5.) The long, hook-like point, above referred to, is not a simple ridge of trap, like that from an ordinary fissure, but consists, as seen along its northern side (Plate VI), of a series of rounded ridges which increase in height to the westward, like those of the elevated surface of trap on the other side of the Triangle. Moreover, all these wrinkle-like ridges, concave troughs and oblique walls, have a general parallelism. (6.) The embossed surface north of the Triangle has lost, through glacial abrasion, as a consequence of its elevation above the general level, all of the sandstone once covering it, even to the foot of the mountain, excepting small portions in two of the troughs. Farther north the sandstone remains in some places nearly to the 300-foot contour-line. (7.) The trap of the embossed area that was thus uncovered suffered little from the abrasion; for the rock of the surface has the fineness of grain and other characteristics of the contact rock. This is true also of the trap of the southeast point. Moreover, in many places on this point below 300 feet, the trap contains imbedded fragments of the sandstone which fell into it while it was still liquid. The trap of other parts of West Rock ridge rarely

shows evidence of abrasion below a level of 300 feet. On the contrary, above this level it has lost by abrasion the fine-grained, brittle crust-portion, and presents at surface the coarseness of crystalline texture that belongs to the interior of the mass.

(8.) Another very important feature of West Rock is its affording a long east-and-west section through the breadth of a great trap range, exhibiting the contact-plane for several hundred feet of the outflowing trap and the underlying sandstone, as described and figured beyond.

The map, Plate VI, has the walls, troughs, and ridges of the surface shaded, to bring out better these features of the original surface of the trap. The southern front of the Rock has been made by degradation and hence has no shading. The southeastern point owes its straight outline on the south side to the quarrymen and the joints in the trap. The map shows what remained of the point in 1880. There is much less now.

The Supply-fissure.—The inclination and width of the fissures supplying the liquid trap for the West Rock range are undetermined. Exposures that will afford the facts are most likely to be found along the eastern base of the ridge. At one place where the surface of trap had been uncovered but not abraded, which was seemingly favorable for a safe conclusion, the slope was 25° to 30°, and suggested the angle of 30° for the inclination. But the trap at the place may have been part of the *outflow*, and not that of a dike. Observations along the eastern slope of the range farther north may obtain decisive facts.

The Outflow.—The slopes of the higher parts of the West Rock ridge, the pitch of the columns of the western front, and the resemblance in features of West Rock to East Rock, lead to a like conclusion for the two, that the outflow was laccolithic; in other words, that the liquid rock forced its way between layers of sandstone, and made the chamber it occupied. The present thickness of the mass is nearly 250 feet. The overlying sandstone is to a large extent the weak, chip-making rock of dark red and purplish color already described.

It is remarkable that a rock of so feeble coherence could have been lifted in the way mentioned.

The questions suggested by East Rock here come up again: Whether the feeble slope of the surface from the west edge of the summit eastward to the 300-foot contour-line, and the small thickness of the trap, are due to abrasion, or whether the present conditions are nearly those of the original outflow. As the length of the outflow is nearly 500 yards, the mass, if forced up between layers dipping 25° eastward, would have had a much larger amount to lose by abrasion than in the case of East Rock.* Speculation is here set aside by the actual east-and-west section of the Rock which is presented along its southern front, and is shown in part on Plate VII, from a photograph.† It exhibits the trap resting, to the eastward, on a tilted layer of the sandstone, the dip of which eastward is 25°. We are left to conjecture as regards the eastward and downward continuation of this layer to the supply-fissure (which the further removal of debris might perhaps uncover). But we know that the trap continues up this sloping layer for

* The thickness does not admit of calculation, because the only datum besides the dip of the sandstone, is the height of the bottom of the trap over the sandstone on the west front (about 200 feet); the height of the outflow where it left the fissure is not ascertainable.

† The fine photograph was taken by M. W. Filley, of the firm of Bundy & Filley, of New Haven. The sandstone has here been exposed to view by the removal of the debris for macadamizing. The irregular line in the plate a third of an inch above the sandstone was the limit of the talus or debris slope; and the line below the sandstone is the profile of the quarry wagon road. Along the part of the section represented, the height of this road is ninety to one hundred feet. If the debris were wholly removed to the bottom of the slope, the height of the sandstone exposed to view would be, where greatest, over 150 feet.

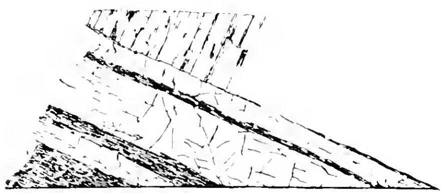
The photograph does great injustice to the view in the diminution of the vertical as compared with the horizontal scale, and also in flattening the angle of dip in the sandstone. 200 feet measured on the quarry road reaches from the eastern point of the sandstone section westward to within twenty-five feet of the line of the deep notch in the columnar front of the Rock (the place where the first section of sandstone ends); but this length applied vertically to the front above the road would make it only 180 feet in height, when in fact this height where greatest is over 300 feet. This error arises partly from the fact that the view was taken from the terrace opposite, which is only sixty feet high, but more from the error in an ordinary lens.

seventy-five yards from the commencement of the outcrop. It conforms to the theoretical view of an outflow as presented in fig. 10, on page 19.

But on reaching the end of the seventy-five yards, there is a change. The trap beyond rests on the edges of the layers in a series of ledges of the sandstone. Moreover there is but little rise westward along the floor; for a line drawn along the top of the ledges would be almost horizontal, and have therefore near parallelism to the surface of the trap at the summit west of the geodetic station.

The following figure represents the eastern extremity of the sandstone for a height of fourteen feet, together with the

13.



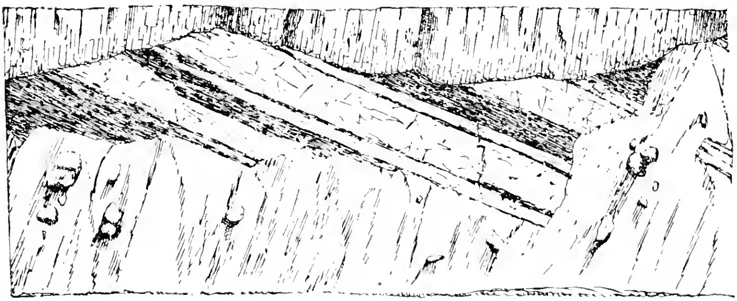
base of the overlying trap. The rock is partly a hard-baked granitic sandstone, and partly the feeble shaly chip-making purplish-red sand-rock. The trap columns above the sandstone have in the lower part an inclination of 20°, approaching thus verticality to the surface of the sandstone; but, higher up the bluff front, there is a gradual change to 5°, which is the prevailing inclination.* The upper layer of the sandstone where uncovered shows a surface without breaks or much unevenness.

A section of the sandstone, with the trap above, for the next seventy-five yards is represented in the following figure. The fact that the trap when melted flowed over the upturned edges is manifest. The chip-making rock constitutes much of the mass, and at its contact with the trap it is scarcely changed in color or texture. The trap is far more finely columnar than that to the east over the single sandstone layer, and probably

* The angles of inclination here recorded are those presented to an observer in the front view of the rock here described.

because moisture reached the trap freely from between the upturned layers. Other sections farther west are of similar character, excepting that the apparent dip is less. They may be followed westward along the quarryman's road for 400 yards, when they begin to pass into the normal sections of the western front, that is, sections in which the lines of bedding are horizontal because they are in the line of strike of the sandstone.

14.



The question here arises: Did the flowing trap, owing to its movement and weight, wear off the layers of sandstone and so make the succession of ledges on which it rests; or did it escape from its confining cover of sandstone into the open air and cover in its flow the exposed ledges of the region. The former is probably the correct view. Had the flow become subaerial there would have been at once a decline westward in the level of its upper surface; for the level would have fallen as soon as the resistance from confinement ceased. There is no evidence of such a decline. From points on the summit close to the western precipice the surface for the first 300 yards has generally a slope eastward of 1 to 4, or 1 to 5, corresponding to a pitch of 14° to 11°. The decline is eastward; not westward. Such a rise westward, even if only 5°, would be an impossibility except in a covered passage-way, that is, in the present case, one having a cover of the sandstone. Other evidence bearing in the same direction is afforded by the position of the columns along the western front, which pitch westward 15° to 20°.

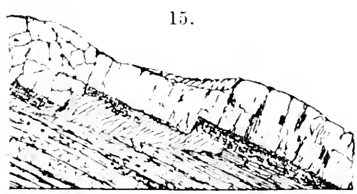
The summit slope eastward of 14° to 11° is less than the dip of the sandstone, and favors the conclusion that the underlying sandstone was in many places torn up by the heavily moving liquid trap, while left in place elsewhere. The floor so made consisted of alternations of wide strips that had the regular dip of the sandstone, with others abraded down to nearly flat and ledgy surfaces; and the former prevailed sufficiently to determine the direction of the contractional fracture-planes or the columnar structure. A reduction so nearly to horizontality as that shown in the south front of West Rock along with parallelism in the profile of the summit may not be common.

West Rock teaches that the section of East Rock in fig. 11, p. 21, may be no exaggeration. Yet it is more probable that the original condition was intermediate between this position and that indicated in this diagram.

Sections similar to that in the south face of West Rock may be looked for, with some probability of success, among many of the trap-ranges of the Connecticut Valley wherever they terminate in transverse sections. All that is necessary to ascertain the truth is to remove the talus of trap debris.

Three miles east of New Haven (in East Haven) a section was opened in cutting for a carriage-road through the second trap ridge west of Saltonstall Lake; it is but a few rods west of the railroad station. The facts are in all respects similar to those of West Rock, as shown in the annexed figure. The

15.



trap covers a series of ledges of upturned sandstone, and shows no traces of displacement subsequent to its cooling. The sandstone is intersected by extensive nearly vertical frac-

tures, whose surfaces, owing to friction, are scratched and polished; and the larger planes extend up through the sandstone without any appearance of corresponding displacement in the trap. Moreover these polished slickensided surfaces have the white porcellanous coating common in the region; probably made by the grinding of the feldspar of the sandstone in the mutual friction of the walls.*

The trap of this ridge, at a higher level above the sandstone, is more or less chloritic and in many places amygdaloidal. Part of the amygdules are slender cylinders, two to three inches long and like pipe-stems in size, occurring often in groups—the result probably of the sudden vaporization of particles of liquid carbonic acid.

In the railroad gap through the Saltonstall Ridge, the first west of Saltonstall Lake ("Pond Ridge" of Percival), the sandstone appears to lie in a similar manner unconformably beneath the western extension of the trap. But the section is now too much covered by debris for a satisfactory observation. Two miles east of the Saltonstall ridge in Branford, as described by Mr. E. O. Hovey,† the trap of a short range, the easternmost in this part of the sandstone region and near the gneiss boundary, overlies the *upturned* edges of the sandstone, and there is between the two rocks a layer of sandstone conglomerate containing nodules of trap, which he attributed to the rubbing action of the flowing trap on the sandstone.

These facts, ranging in this part of the Connecticut Valley over the whole breadth of the Jura-Trias formation, from the

* At all the East Haven quarries, and in the ledges elsewhere exposed to view, these evidences of displacement and of much friction attending it abound. Fragments as large as the hand, slickensided on both surfaces and over planes of cross-fracture, are common; and so are walls of various inclinations hundreds of square yards in area. The sloping upper surfaces of the sandstone layers laid bare in the quarrying are sometimes polished and scratched in the direction of the dip for many square rods. There is abundant evidence of a vast amount of movement, though movement in a small way, during the progress of the upturning in which the sandstone received its universal eastward dip.

The section represented in fig. 15 has lost much of its original distinctness by the sliding down of debris from above.

† The American Journal of Science, xxxviii, 361, 1889.

west side of the New Haven region where the trap is of the compact non-vesicular kind to the dikes of vesicular trap toward and near the eastern gneissic border, have great importance in their bearing on the subject of the other Jura-Trias ridges. The more eastern are placed by Professor Davis among the ridges made of horizontal subaerial flows, ejected before the upturning of the sandstone; and the more western he has regarded as horizontally ejected and subsequently upturned, although admitted to be interstitial intrusions. Neither of these conclusions are sustained by the facts which have been presented.

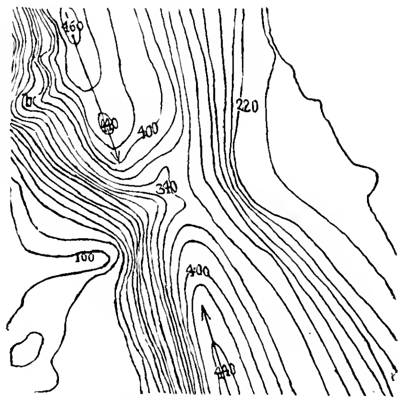
The facts prove further that the era of disturbance or of the upturning of the sandstone was not due in any way to the ejection or heat of the igneous rock. The latter event, although so extensive, was simply incident to the disturbance; the upturning preceded the eruptions.

Effects of Obstructions to the outflow.—Although the trap of West Rock—that is of the southern part of the West Rock ridge—is not divided into several areas, other effects of obstructions may be looked for, since the hanging wall of a large inclined fissure is sure to have its downfalls. The gaps or notches in the ridge indicate incipient division, and may be among the effects from such a cause. They may have been produced also by local narrowings of the fissure through horizontal or oblique movement of its walls, or in other ways; and it is a question whether the results of these two modes of origin can be distinguished. The deeper and more abrupt notches we should be disposed to refer to the former cause.

As the Bache map of West Rock ridge indicates by its contour lines, within a mile and a quarter of the south end of West Rock, there are three gaps. Two are included on Plate II. At the first, the height of the ridge falls off sixty feet in the course of 500 yards. The second, situated 300 yards farther north, and called the "Judges' Notch" because near the "Judges' Cave," is similar to the first in depth, but narrows more down the western front. Half a mile farther north is the third, called the "Wintergreen Notch." It is

one of the larger gaps in the ridge. Along the summit, both from the north and the south, there is a descent of 100 feet, from a height of 440 feet to 340. Figure 16, from the Bache map, exhibits the facts.* The decline is gradual on the south side, but very rapid northward; in the latter direction the level of 460 feet is reached at the same distance from the center of the gap as 440 on the south. This third gap is probably one of those caused by obstructions to the outflow, whatever the fact with the others. The stream, in consequence of the obstruction, reached a height at the gap of but 340 feet; but just beyond, the lavas that had been held back, made the abrupt rise in the ridge to 440 and 460 feet. The correctness of this explanation appears to be sustained also by the abruptness of the rise in the slopes east of the gap, as the contour lines in the figure show, and the great breadth of the nearly horizontal area farther east. It will be observed also that the summit of the ridge north of the gap is farther to the west than that on the south. (Arrows are inserted to make this distinct.) It is so because any given amount of trap depends for its height on the distance it flowed westward up the inclined sandstone layers. It may be observed that not only the height, 460, but also 440 on the north side is to the west of 440 of the south side; but the height of 440 to the north is probably produced with a less thickness of trap. This notch is 300 yards

16.



Wintergreen Notch.

* The west side of the ridge in this part, as elsewhere, is the precipitous side, bold columnar above. Its upper 200 to 225 feet usually consist of trap, and the part below of sandstone; but the junction-plane at the Notch is concealed by trap debris, so that its actual height is not determinable.

south of the Buttress dike described on a former page; the position of this dike is shown on the above figure at *b*.

This example will suffice for illustration. Other gaps in the ridge occur farther north, but they are outside of the region here under consideration.

Obstructions to the outflow of lava while it was making its way between the layers of sandstone are also possible through any cause that would prevent the lifting of any portion of the overlying rock. The area of the Triangle has been described as an area of sandstone within the proper limits of the trap range. This sandstone was not lifted like the rest of the overlying stratum. Instead of this, it remained in place for the most part, and hence, forced the liquid rock to pass to one side of it. The lava, mainly took the north side; and so the trap of that side had its surface raised in level above the rock north and became the elevated embossed area already described. The great sloping trap wall making the north side of the Triangle is the wall of an oblique fissure in the sandstone formation. Along this fissure—45° in inclination,—the sandstone of the south side, or that of the Triangle, lay unmoved or nearly so, while that of the north side was shoved up as the lavas came in below. Other walls, and the small ridges both north and south of the Triangle, are evidences of similar fractures, in parallel directions, with analogous results. The unlifted sandstone was in some way put under a strain that produced the parallel fracturing and movements.

The origin of the southern or western walls of West Rock is sufficiently explained in the remarks on this subject respecting East Rock (page 20).

The southern front of West Rock has a columnar aspect. But in reality no columns stand out with the boldness they have in East Rock. The surface is mostly made up of the cleavage surface or joints that are in its plane; and where there has been quarrying, these joints have great width as well as height.

3. Relation of the east-and-west and north-and-south fissures, and the origin of these courses.

These two courses of fissures are so locked together in the New Haven region that they evidently are results of one system of movements. They occur together in Pine Rock; and West Rock has the general trend of the Pine Rock ridge represented in the embossed area and the southeast point. Mill Rock ends to the eastward in a south-southwest fissure, transverse to its main course which is apparently parallel to the adjoining part of the East Rock trap. East Rock commences with a nearly north-and-south course, but bends around to east-southeast. Mill Rock and Pine Rock are not necessarily synchronous in eruption with East Rock or West Rock, but they belong to one epoch of disturbance.

The origin of these courses is not fully ascertained. I have long explained the north-by-east trend of West Rock, and of the other ridges of like direction to the north, on the general principle that the mountain-making forces of Eastern America operated over any part of the area, as a general thing in the same direction from Archæan time onward, examples occurring in the Taconic and Jura-Trias elevations of the western half of New England. In accordance with this view the strike of the Jura-Trias should be that of the underlying crystalline rocks. It does not follow that a like dip prevails in the schists beneath. It is true however that the predominant dip in them, and in the Jura-Trias fissures and bedding, is eastward. This last fact seems to favor the suggestion of Professor Davis that the foliation of the underlying schists has determined the courses of fissures in the Jura-Trias area. This suggestion would have support in the fact, were it not that in New Jersey, where the same is true as to the dip of the underlying schists, the Jura-Trias fissures and bedding dip westward.

In the New Haven region, the idea of an accordance between direction of foliation in the schists and of fissures in the Jura-Trias finds no support. The West Rock ridge crosses the line

of strike of the metamorphic schists two miles west of it at an angle of 20°. East Rock has an east-of-north course only in its northern extremity, and curves around through nearly half a circle. Pine Rock and Mill Rock cut across any probable course of foliation in underlying schists and do it on lines that differ 50° in trend.

The origin of the east-and-west courses, which commence in the extremity of West Rock and continue to Whitney Peak, four miles, may have its explanation suggested by the remark under (4) on page 2. Or, it may be a consequence of the movement attending the production of the north-and-south fissures, and local to the New Haven region. The subject at present is one of conjectures.

On account of the interest of the dynamical question here brought into view, I introduce another illustration of the facts from a transverse ridge only six miles north of Whitney Peak and Mill Rock. It is called Mt. Carmel (Plate I). The ridge is three miles long. It is higher than those already considered, the most elevated point being 736 feet above high tide.* But height means here, not larger accumulation of igneous rock or trap, but, simply, greater emergence above the sea-level; for this increase northward of height runs parallel with a like increase in the height of the metamorphic ridges just west; and it is continued, at a diminished rate, into Massachusetts.

Mt. Carmel has resemblances to Pine Rock. Its mean course is E. N. E.; and a north-and-south trend exists in its western part. But the north-and-south portion in Mt. Carmel is a large feature in the ridge and has direct continuity with the east-northeast portion.

The ridge is divided by a very deep and open gorge, into an eastern and a western section. The gorge is often called the "Neck," and the high summit adjoining it on the west, the "Head" of the "Sleeping Giant"—a name suggested by the form of the ridge as it appears lying on the northern horizon. Both have northern and southern slopes of sandstone, the

* According to the leveling of two parties under Mr. Bache.

southern going about half way to the top above its base, and the northern reaching a greater height.

The western section, while high and massive at its eastern extremity, falls off rapidly to the westward, and in half a mile is reduced to a narrow trap ridge not exceeding 100 feet in height above the adjoining country. Through this part within 300 yards, pass Mill River, a north-and-south carriage road (N. 20° W.) without change of grade, and, a few rods farther west a railroad. Along the railroad, and between the carriage road and the river, the course of the trap changes from about north-and-south to N. 10° E.; and as it crosses the river to N. 20° E. Thence it continues on to the summit, widening and increasing rapidly in height and curving still farther eastward.

At the section in the railroad cut, the trap is seen resting on its south wall of sandstone, the wall dipping about 45°—apparently indicating that the dike has this pitch. Between the carriage-road and Mill River, the north side of the trap has in many places a westward dip of the same angle, confirming the conclusion from the railroad section as to the large dip of the fissure. It is thus proved that the western section is a continuous mass of trap of gradually changing course and magnitude; and that it is strictly "transverse" in direction only along its eastern end. It is a dike to the westward and probably so throughout.

The eastern section is made one continuous mass of trap by Percival, and one also with the western portion. It is divided from east to west, as he states, by a valley, and in the valley there is a spring giving out a streamlet which flows northward. There are gaps in both the southern and northern sides, dividing them into a series of elevations. These elevations are indicated on Percival's map, so as to look as if he regarded them as separate dikes; but this is contrary to the description in his Report. I have looked for sandstone in two of the gaps of the south side, east of the "neck," and have found evidence in each that the trap is continuous, and descends in these gaps nearly half way to the base of the mountain. In the east-and-

west valley the spring and streamlet are probable evidence that there is sandstone beneath; and on this ground, it may be that there are, in this eastern part of Mt. Carmel, two parallel east-and-west dikes.

Mt. Carmel appears to be a combination of dikes, without the "buried volcanoes" supposed to exist there by Professor Davis. In the view from the west side of Mill River there are in sight nearly 600 feet in height of massive trap, having no subdivision into sheets or layers, and nothing to suggest the idea of lava-streams in the depths below.

The union in this small ridge of approximately north-and-south and east-and-west courses is further proof of their mutual dependence in the system of movements attending the Jura-Trias mountain-making of the Connecticut Valley. But its origin remains unexplained.

Concluding Remarks.—A review of the principal conclusions in this paper is given in its introductory remarks (page 5), and a recapitulation here is therefore unnecessary.

The reader may have been led to the idea that the author would make the West Rock Ridge typical for other ridges of like features in the Connecticut Valley region, in disagreement with the conclusion of Professor Davis who holds that in the case of most of these ridges, if not of all, the trap was poured out in one, two or more horizontal sheets, separated, and overlaid horizontally, by beds of sandstone, and that the whole was afterward faulted and tilted so as to make the ridges. The author acknowledges that he is inclined to make the conclusions he has reached general. He, however, admits that he has not made the structure of the other ridges of the valley a special study. He believes his observations sufficient, however, to authorize the statement that a more intimate knowledge of the facts is required before any adverse views can be regarded as established.

WALKS AND DRIVES.

SEVERAL reasons have induced the writer to publish in this place the following scheme of Walks and Drives.

The region of New Haven is remarkable for the variety and attractiveness of its scenery. The "Four Rocks" standing about its inner precincts, the distant background of forest-covered ridges on the west, north and east, the three rivers and the lakes, the city spreading widely over the plain, the Bay, the Sound with Long Island on the southern horizon, make an ever-varying and ever-charming landscape.

It is therefore most desirable that the citizens of New Haven, and especially the young new-comers, should know where to go for a pleasant walk, what is to be seen, and how long the way. The exercise thus obtained is the best possible for the reasonable athlete who has health, and not victory alone, in view. Pursued systematically, it would become a habit and afford pleasure and physical good through a life-time.

Besides scenery, there is instruction to be gathered from nature by the way. There are rocks, and there are flowers and animal life of the land and of fresh and salt waters, to reward those who are interested in what is behind the scenes. The rocks stand up to be looked at, and also to answer the enquiry as to their origin and history. As information on this latter subject is thought worthy of attention in these days, is exalting to the appreciative student, and is especially varied in the vicinity, the author has desired to make the New Haven region a source of instruction to teachers and students, and to all lovers of science and scenery.

The Walks and Drives are enumerated in a circular order from East Rock around by the left. The walks may often be shortened at option by taking the horse-cars. The distance from the center of the city square to the four Rocks is $2\frac{1}{4}$ to 3 miles;

to the Yale Athletic grounds, out Chapel Street and Derby Avenue, 1½ miles; to Allingtown, 2 miles; to Savin Rock, on the Sound, 4 miles; to the Old Light House, on the east cape of the harbor, 5¼ miles; to Tomlinson's bridge, 1¼ miles; to East Haven village, 3¼ miles; to the bridges over the Quinnipiac in Fair Haven, a little over 1¾ miles; to Whitney Lake Boat House, 2¼ miles.

The variation of the compass at New Haven is 9½° westerly; whence N. 45° E. compass course is N. 35½° E.; N. 10° W. compass course is N. 19½° W.

On the map the parts colored red are those of the trap; the rest of the region is underlaid by sandstone.

1. To East Rock—A Walk or Drive.

The best route for the first visit to East Rock is by Orange Street and the Farnam drive (the road leading north from the Orange St. bridge). It is the best for the succession of views and for the study of the features of the Rock. The views are

1. Profile of Mount Carmel.

greatly varied in consequence of the complicated structure of the Rock (Plate III) and the boldness of its outlines, together with the nearly universal covering of forest. There are hence shady recesses as well as distant landscapes. Moreover these landscapes are widely diverse on account of the position of the Rock. To the west are Mill River, with the long and winding Whitney Lake, the city in a forest of elms, the harbor, and the West Rock ridge and the Woodbridge heights as the western boundary. On the east lie the green meadows of the Quinnipiac, as large as the New Haven plain, bounded along the horizon north and east by trap ridges in long succession; and although simple in its elements, the landscape is one of the finest which the Park affords, especially as seen on the road northeast of Whitney

Peak. Mt. Carmel, or "the Sleeping Giant," lies on the northern horizon, with lower ridges westward to the Bethany Notch and West Rock. To the northeast is Lamentation Mountain, with a bold western front, not far from Meriden; then southward, come Higby mountain between Meriden and Middletown, Mattabeseck mountain against southern Middletown, and the three Durham mountains, (the middle of which,

2

2. Profile of the three Durham trap-ridges, Tremont in the center, and Pistipaug trap-ridge to the right (south.)

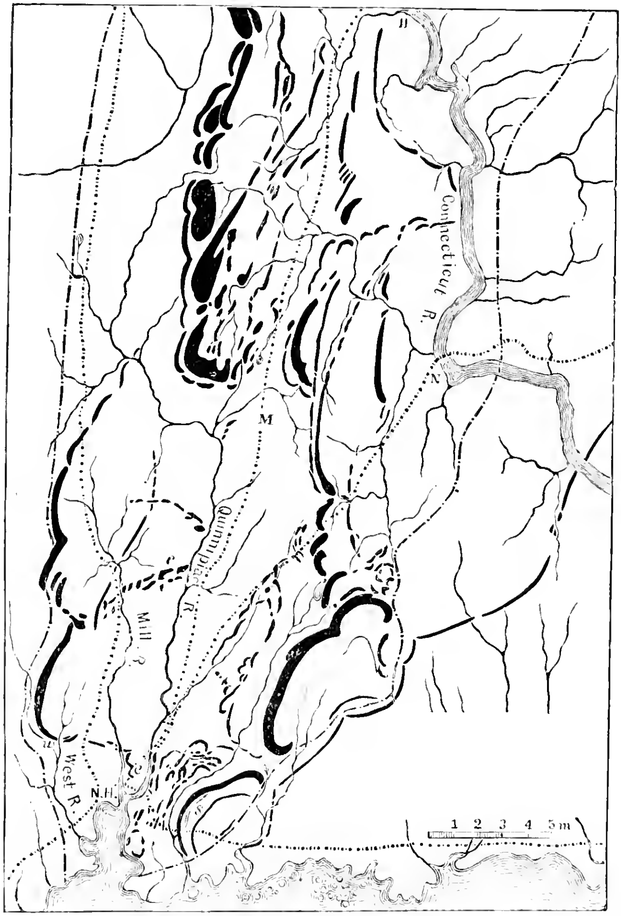
having three peaks, is the Tremont of Percival); then, Pistipaug ridge on the east border of Pistipaug Lake, the long even-topped Totoket range in North Branford, and last, Saltonstall ridge, bordering Saltonstall Lake; and in a nearer range, directly east, the rounded summit of Rabbit or Peter's Rock, noted for its large and nearly vertical columns. They derive interest from the fact that all are trap ridges, and of the same epoch of eruption with East and West Rocks.

The positions of these trap ridges are indicated on the following map of the trap-areas of central Connecticut south of the latitude of Hartford (H), from Percival's Geological Report of 1842. The Saltonstall line is seen at S abreast of Saltonstall Lake, the Pistipaug, against Pistipaug Lake, and Lamentation Mountain northeast of M, Meriden; and from these points and the profile in fig. 2, the others of the series on the east are easily distinguished.

Northwest of M, are the Hanging Hills, the commencement of the line that extends to Mt. Tom, in Massachusetts. At *w* is West Rock, the south end, it is seen, of a long curving line which dies out just west of the Hanging Hills of Meriden. At *e* is East Rock, an isolated ridge. At *c* is Mt. Carmel, apparently a group of trap-areas, but really for the most part a single area having several elevations. Along *mn*, and *op*, are the eastern and western boundaries of the Red Sandstone region. Middletown (N) is near the eastern.

The view of East Rock from the vicinity of Orange St. bridge is shown in Plate IV. Its battlement-like front is well set off by the foliage about it. The large columns appear to rise vertically from deep foundations; but they have really an

inclination eastward of 20° to 23°, as may be seen in profile views. Moreover, half way to the summit—correctly at a height of 155 feet—the bottom of the columns may be seen resting on a bed of grayish and reddish sandstone; but the columns in this



Trap-areas of Central Connecticut: From Percival.

lower part are small. This outcrop of sandstone may be reached by a rough path over the stones. But, although delicate feet have trod it, most will be contented with a sight of some lower layers of the sandstone formation just opposite the end of the bridge.

There is, however, a difference in the interest of the two outcrops. The sandstone of the upper outcrop was directly beneath the melted trap at the time of the ejection and became hard-baked by the heat. The lower was too far away to be much changed ; for heat in rocks travels but a short distance from its source unless there is much moisture at hand to be converted into steam for its distribution. Nearly on the same level (150 feet), there is another place, a little east of a vertical line through the Refreshment House of the summit, where the junction of the trap and sandstone is open to view. But it is not intelligible from below, and is reached with some difficulty.

A short distance north of the Orange Street bridge, trees and shrubbery have gained a foothold up nearly all the steep front ; and here Tyndall, in a solitary walk in the winter of '72-'73, when snow and ice covered the cliffs, climbed to the summit—no great feat for the Alpine climber, but still much enjoyed.

Continuing northward beyond Rock Lane bridge, the sandstone crops out at intervals. Soon, trap has its place, and grows bold toward Whitney Point and its Summer House. Then comes in again the sandstone. The circular plot of land in front of the Summer House has trap over its southern half and sandstone over the northern ; and the hard light gray portions of the latter are in some places greenish from the presence of a little epidote. These transitions from sandstone to trap, and the reverse, are indicated on the map of East Rock, which shows, by the red color, that the Whitney dike has here been passed. Other such transitions may be seen on the way, and the map is referred to for their explanation.

Outside of the stone parapet on the road where the height is 254 feet (see map) a bare wall of trap descends at a high angle toward the depths from which, miles below, it originally came up melted. It is exposed to view for a height of 50 to 60 feet.

At the summit of the Rock, the view off on a fine day is charming. But although at the top, it does not include the country on the east or north, unless an ascent is made within the narrow shaft of the monument. The people's tower for a panoramic view, of ample dimensions, with broad and easy stairway, a landing above large enough for scores at once, and no higher than is necessary to afford a view clear of obstructions, has not

yet been made. A good site for it, and one very nearly as high as that on which the monument stands, would be the high ground a few rods south of the Refreshment House, where it would look well from below if suited in style to the foundation.

On the descent, return to the loop in the road, at a height of 268 (Plate III), and there take the "English Drive," going southward. On rounding the steep southern side of the Rock, between the heights 227 and 216, Quarry Corner is passed, where quarrying was pushed vigorously when the question of taking possession of the grounds for a Park by the city was pending. The deep gashes however have made a fine display of the nearly vertical joints or divisional planes of the rock, (resulting from contraction on cooling,) and opened a broad southwestward surface that glitters brilliantly in the sunshine from the rosettes of garnets that cover it. There were formerly minute octahedrons of magnetite also, but the latter have mostly disappeared. The descending road passes 201 and a Summer House between East Rock and Indian Head, and then makes nearly the complete circuit of the latter, passing along its western face above the base (concealed by debris) of the columns Approaching 103, it goes over the trap of the southwest angle of East Rock. Thence it winds around to Orange Street bridge.

2. To Indian Head—A Drive or Walk.

The route from State St. over Snake Rock to the summit of Indian Head takes in the roads not passed over in the previous excursion. Leaving Snake Rock the road passes under a bridge and comes up by the bold southern front of Indian Head. This steep, rocky front, it may be observed, continues eastward below the road, and is part of a long, tail-like extension of the trap to within 100 feet of the carriage road at the foot. It is a good place for further exploration when there is time for it, for it is a peculiar feature of Indian Head, as the map shows. The road continues along the east side and commences the ascent to the summit at its northeastern angle.

The view from the southern side of the summit, near where the road stops, has the forest-covered Snake Rock in the fore-

ground, and brings nearly the whole New Haven plain, from Fair Haven on the east to the remotest limits of West Haven, into one broad landscape. A path leads to the higher summit. From the brow of the Rock the view is much like that from East Rock, but the bold front of East Rock adds an impressive feature. At one point, East Rock may be seen projected upon West Rock, one over the other, like the faces in a medallion.

Indian Head takes its name from a group of trees at the summit, which in former time, as seen from below, looked much more like the tuft on the head of an Indian than it does now.

3. To East Rock—A shady Walk.

Take the path near Whitneyville over the Foot-bridge. When approaching and crossing the bridge there are pleasing views both up and down the river. The path leads to the road and thence is continued across it up to the Hemlocks, one of the rest-places. The rock along the way up and at the Hemlocks is sandstone. The valley just north takes the drainage of the hills, and at its narrower end (at *a*, Plate III) it formerly had a standing pool of water. A well has been sunk at this place to a depth of 18 feet in sand, which has 6 feet of water. The trap area, AA′, is on its east side. Along the road west of it, after some sandstone, the rock changes to the trap of Whitney Ridge; and a little farther northward the precipitous front of the peak may be seen high up amid the foliage. Although so grandly bold, sandstone will be found at its base a few yards east of the road. South of the Hemlocks, at the first eastward bend near 191, there is the end of the sandstone in that direction in a little valley, and just beyond, the trap of East Rock is in full force.

From the Hemlocks a path leads off southeastward, which reaches the road again at a point near 254 (Plate III). About 100 yards out on this path take the branch path eastward toward a quarry in a low ridge of hard-baked sandstone, and near the quarry a path southward which crosses the low ridge and comes down to the foot of the trap wall referred to on page 45. Trees and shrubbery mostly hide the wall; but just south of a juniper

bush there is an opening through which it may be approached. It is well to examine it and see the evidence that the steep wall of trap is the outside of the dike; that it was cooled against a cold wall of sandstone—the east wall of the fissure up which the melted rock came. The sandstone at the foot of the wall is concealed by the soil. That which covered it above was probably carried away by the glacier, which thus left it bare, as we now find it, but, as stated on page 18, did not disturb or abrade the trap. To the eastward is a fine view of the Quinnipiac meadows and the trap ridges on the horizon, commencing on the north with the Durham three. The path now leads southward up the slope over a surface of trap (Plate III), and soon reaches a spring, or water in the course of a little stream; and then a level plot of land, terrace-like, free from stones, with a very steep upward slope between it and the road. At the southern end of this terrace another and better spring will be found, a little below the level of the terrace. Along the path, a few rods below this spring, sandstone outcrops against the trap—the sandstone in pieces as the glacier left it (at S, Plate III); and just north and also east of the spring, a few rods, some fragments of sandstone lie over the surface.

From the spring, take the path leading southward up to the road at 238, and continue on around the steep southern side of East Rock toward 216, passing Quarry Corner and Garnet Bluff. The nearly rectangular intersections of the two systems of joints should be observed and the glittering surface of garnet rosettes on one of the fronts trending southwest; but please leave the garnets to shine; a hammer will only destroy them.

Here a shady zigzag path descends to the road, and just below the road is continued to Orange Street bridge, passing an excellent spring on the way.

Except for a short distance at the top, the rock along the zigzag way down is sandstone; and it is an upper portion of the sandstone which underlies the trap; so that here the trap is faced by sandstone up to a height of 185 feet—the height of the broad area at its top. (Plate III, and page 20).

Another way down is by a path leading from 227 to the road below at 201, and thence by another path to the road and 130, where a branch of the zigzag path above-mentioned commences

its descent. The succession of sandstone, trap, sandstone, just above 130, merits special attention, since it is a cut through the southwest corner of the East Rock trap for which Science is indebted to the constructors of the Park.

4. To the summit of Whitney Peak—A shady Walk.

Take again the path which crosses the foot-bridge near Whitneyville. On the east side of the bridge follow the path northward nearly to the Factory Grounds before making the ascent to the road. The road is reached near the Summer House on Whitney Point, and the path to the summit ascends from it. If the north and south junctions of the dike with the sandstone have not been already observed, it will give interest to the walk to look for them: first on the plot near by encircled by the road; and then, for the sandstone of the southern wall, about 100 yards down the road on its east side. Moreover, between these limits, the trap at one place on the roadside looks decomposed, and has in it along a vein a white mineral which is laumontite.

The path up goes first over trap, and then, for a short distance, over the sandstone of the northern wall. There are various views along the way; but the summit is a solitary place, shut in by the trees, and many will enjoy it the better for this unusual feature.

On the side north of the summit there is a nearly vertical precipice of 70 or 80 feet, which has interest besides that of its own features from its having been laid bare by the glacier. The sandstone was easily removed by the moving ice, but not so the wall of hard trap.

The return may be made by the path that winds around southward, and joins that descending from the Hemlocks.

5. Around Mill Rock and among the Kettle-holes of the Pine Marsh region—A Drive or Walk.

Out Prospect Street, noted for its fine western prospects. The road rises above the general level of the plain along the western slope of Sachem's Ridge—a sandstone ridge thinly covered with

earth, and a little over 150 feet above tide-level where highest. The distance from Grove Street to the Rock is just two miles. Prof. Marsh's grounds are passed on the left, a little over half a mile from Grove Street; the Observatory, on the right 300 yards farther on; and the Reservoir, also on the right, at 1½ miles from Grove. Along the road, the distant part of the western view includes the Woodbridge Heights, the long West Rock Ridge and Pine Rock. Beyond Canner Street—that on the north side of the Observatory Grounds—over an open field on the west, Pine Rock is in full view with West Rock Ridge beyond it; and Wintergreen Notch is seen over the western flank of Pine Rock. At the next crossing—that of Highland Street—the rival Rocks afford contesting pictures in the opposite directions—West Rock, a profile; East Rock, a front view.

Reaching Mill Rock, turn west into "Mill Rock Street," and take the first road going northward. It passes the west end of the Rock, where is to be seen the section represented on page 11.

Go on to the second east-and-west road. Between this road and Whitney Lake in a northeastward direction, near the borders of that remarkable depression, like the channel of a great river, Pine Marsh Creek, are many "kettle-holes." (The position of the Pine Marsh depression is shown on Plate I, and its southern extremity near which there are other large kettle-holes, on Plate II.) Along the route northward to the next road, the kettle-holes are under the pines within fenced property, and in driving, a road a third of a mile east must be taken. Beyond this, a road may be followed (commencing a little to the west) through the forests to the lake. The bridge over Mill River here reached may be crossed and the return made along the east foot of East Rock; or the road directly south may be taken to the east end of Mill Rock and Whitneyville.

In the earliest colonial times the fall of water at Whitneyville was made useful in turning a grist-mill, and as far back as 1642 it was "ordered that there shall be no other mill built for this town, provided that the mill that now is, be fitted so that it may serve the town's occasion to grind both Indian and English corn well." Thus the stream early became "Mill River."

6. To Mill Rock—A Walk.

Out Prospect Street, noting the outcrop of coarse sandstone or conglomerate on the eastern road-side, occurring for 250 yards after passing the residence of Prof. Dexter, and also another exposure of the rock beyond the Observatory Grounds. At the latter locality the eastward dip is plain, and some of the included stones are 6 or 8 inches in diameter. Not more than 6 or 8 feet of earth generally cover the sandstone of Sachem's Ridge, and this is for the most part bowlder clay or till, a deposit of the glacier. The scattered stones or bowlders on the surface are of glacier transportation. Nearly all are of trap or sandstone, the rocks of the valley, a few are of quartzyte, and one or two of gneiss. At Harrison Street, the first street beyond Highland Street (and the first south of the Reservoir), turn west to the next north-and-south street, Winchester Avenue. When 100 yards on the way down Harrison Street, there may be seen, in the field to the south, 100 feet off, a large bowlder. Its length is 14 feet and its probable weight 40 tons.* The glacier may have taken it off from Mill Rock; but more probably from a ridge near or beyond Meriden; for the trap is like that of the largest of the New Haven bowlders. The bowlder is split in two longitudinally, and the parts separated 7 inches. The chief agent in the splitting was a small oak, which began as a seed in a crevice. The tree has been cut down, but a large crop of stems have started up from the trunk.

Continue on Winchester Avenue northward to the west end of Mill Rock. Here the dike may be seen in its full breadth between its walls of sandstone, nearly 210 feet apart. The inclination of the rude columns may be noted; the south wall of sandstone adjoining the dike examined for its shining steel-gray scales of hematite, (the place has afforded also garnets); and also a vein near the middle of the dike, for its laumontite, and another for prehnite (p. 11).

* The calculation is made thus: 32 cubic feet of water weigh a ton (of 2000 pounds). The specific gravity of the solid trap of West Rock is about 3·03 (Hawes), but of the mass of rifted trap of the bowlders, probably not over 2·9. Hence the latter should give $32 \div 2{\cdot}9 = 11$ cubic feet to the ton; the former $32 \div 3 = 10{\cdot}67$ cubic feet to the ton. Consequently a bowlder of the former of 440 cubic feet should weigh about 40 tons.

Take now the road by the south foot of Mill Rock eastward to the end of Prospect Street. Close by, a quarry road leads up the slope to an old trap quarry. From the summit, north of the west end of the quarry, there is a fine view of Mt. Carmel and the ridge which extends from it westward to its junction, at Bethany Notch, with the West Rock Ridge. At the quarry, the mineral prehnite used to be obtained in good specimens. The junction of the trap with the sandstone of the south wall may be looked for south of the east end of the quarry.

Continue eastward along Armory Street to the height of ground between Prospect Street and Whitney Avenue. Here cross the field northeastward to a low bluff of trap where there was once a small quarry. This is the beginning of the dike B B′ (page 11); and in the high sandstone bluffs northwest of it, is the narrow dike, C. The house just beyond the west end of this bluff is the residence of Prof. Wm. P. Blake, geologist and mining explorer, who has travelled extensively over the mining regions of the Rocky Mountains and California. Ascend the low ridge at the old quarry, and a path will be found leading through the woods northeastward to the Whitney Lake Boat-house. Just above the north end of the ice-houses, a few feet west of the road where sandstone makes the roadside, there is an outcrop of trap, which is not too large to be that of a half-buried bowlder. But Prof. Blake, when his road just north was in process of construction found that it was continued northward across the bed of the road, as a dike 5 or 6 feet wide. Its course is N. 35° W., which is nearly toward the trap-area D (Plate II).

By the roadside abreast of the lake, below Mr. Day's store, there is a pot-hole in the sandstone which is a record of the Glacial flood. When cleared of the rubbish it was ascertained that its depth, measured from the highest traces of it on the south side, had been 7 or 8 feet. It was made through the whirling of stones by the rushing waters of flooded Mill River, when the waters were 60 feet or more above tide-level. The north side of the Mill Rock Ridge was here the west shore of the stream. Some of the large stones are still inside the pot-hole. Two similar pot-holes were cut away at the last grading of the road not far below. The flood was made by the melting of the great glacier. A fine terrace, north of the ice-houses, registers,

approximately, the height of the flood along that part of the stream—63-66 feet; and the terrace southwest of the Whitneyville factory, the site of fine residences, shows that the waters there stood at 20 feet above the level of the present dam. The road of Whitney Avenue rises nearly to the top of this terrace as it leaves Whitneyville.

Toward the extremity of the Mill Rock Ridge, the junction of the trap and sandstone may be seen, and, along it, the fine-grained texture of the trap and the short distance to which the sandstone is hard-baked; and, by going to the top of the dike, the inclination of the columns may be noted and the little apparent width of the dike (p. 14). At the point, there are traces of a laumontite vein, like that at the west end.

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7. To Pine Rock—A Walk or Drive.

The most instructive route to Pine Rock is by Goffe and Crescent Streets; it reaches the Rock at its west end: distance $2\frac{3}{4}$ miles. The east end is 3 miles distant by Dixwell Avenue and Arch Street; but this route may be shortened by taking a Shelton Avenue car to the termination of the track, and then continuing north a block to Morse Street, then turning west. Morse Street is nearly in line with Arch.

Crescent Street passes by the west side of the Beaver Pond Meadows. These "Meadows" occupy a remarkable depression in the New Haven plain, over a mile long and several hundred yards wide. The small stream is supplied from subterranean sources; and at some points in it the water never freezes, not even when the thermometer falls to zero. Until recently it has been more a surface of marshes than of meadows, and an excellent botanizing ground.

Besides the great depression, several "kettle-holes," 50 to 100 feet or more in diameter, may be seen on the west side of Crescent Street (see Plate II, for these and many other kettle-holes). On passing by the end of Dyer Street—the first street that enters Crescent Street from the west—a remarkably fine "kettle-hole" will be found north of Dyer Street; it has water at bottom on a level with the water of the Beaver Pond depression. Half a mile

north the outlet of the brook is passed. It flows westward along a channel in the plain wide enough for a great stream, and empties into West River. The fall of the waters and the amount have been sufficient to supply one mill and give half supply to one or two others. By cutting down the outlet the meadows will be to a great extent drained. The depth of the Beaver Pond depression east of the outlet, down to the bottom of the soft earth or mud, is *25 feet below mean tide.*

In sight of the facts, the question as to origin presses: why so large a depression here when nearly all the rest of the New Haven plain was built up to regulation height?

A suggestion: it may be that along its course the depression of the surface was so much deeper than elsewhere that the sand and gravel from the glacier, deposited by the glacial flood, did not succeed in filling it; further, that the depression was made by the glacier in the Glacial period or that preceding the flood; that the glacier, moving S. 15° W. through the gap between Mill Rock and Pine Rock, and being 1000 feet or more thick, ploughed deeply into the soft sandstone below; that it thus made the Pine Marsh Creek depression, north of Mill Rock, and, after a partial interruption, the Beaver-Pond depression; and that it kept on the work of excavation southward to the Bay, making the channels of East Creek and West Creek. Plate II shows the south end of the Pine Marsh depression at Pi, and the positions and extent of East and West Creeks; and it also illustrates the fact to the eye that the kettle-holes are a part of the results, since they are connecting links between the greater depressions. These interesting natural features will soon disappear through the conversion of the meadows into a city park.

Directly west of the meadows rise the Beaver Hills, to a height of about 100 feet. This elevated sandstone region, like that of Sachem's Ridge, is plain evidence that the glacier for some reason failed to excavate along it. The reason is found in the existence of a resisting trap dike just north for each of the ridges. If in planing a board the cutting edge strikes the head of a nail and has a notch made in it, the surface of the board beyond the nail will have a little ridge on it corresponding to the notch. So the glacier was notched by the trap ridges, and the Beaver Hills and Sachem's Ridge are the little ridges con-

sequently left on the surface of the New Haven region ; and the direction of these ridges shows the direction of the movement of the glacier. Other sandstone ridges also were shaped by glacier-planing.

Reaching the end of Crescent Street, next take Wintergreen Street, a few rods south, to the west end of Pine Rock—where the small trap dike A (p. 7), is in sight. The road along the southern foot of the Rock (which is poorly passable for wheels) leads to a point abreast of the gap, between B′ and C, where a path offers the best way of reaching the top. At the summit of the gap the strange northern hills of trap, E E′, which make the head and neck of the duck-shaped dike, may be explored. On the way eastward to the highest point of the Rock, the bare northern wall of the dike, 50 feet in height as left by the glacier, is worth seeing ; and still more the fine view from the summit. Just west of the highest point a surface of trap sloping southward has the pitch of the columns.

The descent may be made by the east end of the Rock. At this east end the trap and sandstone of the northern wall may be seen in contact, the latter very hard from the heat to which it was subjected. In the quarry, just south, several minerals may be collected (p. 7), and the laminated appearance of the trap may be well observed. On the low part of the northern slope of the Rock, there is a fine spring.

The "cave" at *v* is one of the interesting spots about the Rock, because of the exposure in its roof of the southern wall of the dike and the view of the oblique columns above it (p. 8). It may be best examined before making the ascent of the Rock.

On the return from Pine Rock take the road at the east end, leading southward and eastward by Arch street to Dixwell Avenue. It crosses the northern part of the Beaver Pond Meadows.

8. To Mount Carmel—A Walk or Drive.

Mt. Carmel (Plate I) is about six miles north of Whitneyville. As the profile on page 42 indicates, it has three gorges on the southern side of its summit. The western or that of the Neck of the "Sleeping Giant," is the deepest and has a precipice of

200 to 300 feet facing eastward. The other two—the second, and third—are between 100 and 200 feet in depth. The highest point of Mt. Carmel is not on the "Head," but on an isolated peak a little north of the second gorge. For the ascent of Mt. Carmel take the road eastward, and to reach the Neck turn into the field just after passing the first road on the right; for the second gorge turn in at the bridge after passing the second road; for the third notch turn in just after passing the third road.

If the object of the excursion is to take the view, it is best to ascend the "Head," which has a path to its summit. But for a longer and more interesting trip, including a visit to the geodetic station and highest point, the path should be soon left and a climb made over the broken rocks to the top of the east side of the Neck—from which also there are fine views southward. Going eastward along the summit the second gorge is reached. It has a bold bluff along its northwest side, and just opposite, rises the highest peak, that of the geodetic station of the Coast Survey. To reach it a descent must be made into the gorge and a climb on the other side. Descending northward the central depression of the mountain is reached, with its small run of water and a spring at its head. This excursion may be extended farther east, and the descent made toward Wallingford; or the return may be made down the second gorge. On the descent by this gorge about half-way down comes the change from trap to sandstone. Just before reaching the sandstone, the trap is finely glacier-grooved in a north-and-south direction, and one of the grooves is 2 feet wide and 6 inches deep. The sandstone below the trap affords interesting specimens of the yellowish-green mineral, epidote. Much of the sandstone about the mountain is a coarse conglomerate.

After descending, if not done before making the ascent, the trap along the railroad and from there to the river should be examined, as it is the low western commencement of the great mass which makes the "Head." At the railroad, on the west side of the cut, the trap rests on the sandstone, as stated on page 39; and, on the east side, great masses of sandstone are included in the trap.

9. To Centerville and the Gap at Mt. Carmel Village; A Glacial Excursion—A Walk or Drive.

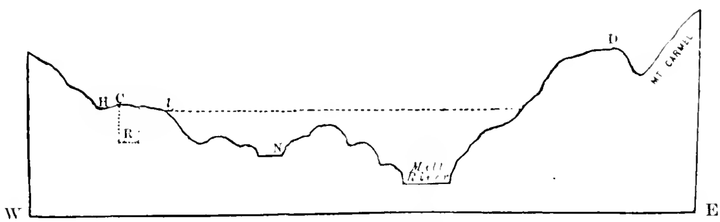
The narrow gap at Mt. Carmel village, by the west end of the mountain, about 250 yards wide, has the lofty "Head" of Mt. Carmel on the east, and lower bluffs of trap on the west. The only spots that are free from the trap, and therefore level, afford scant room for Mill River and the carriage road. The railroad has made its own way by a cut through the western bluff.

The gap, being thus a convenient place for an ice-dam during the melting of the glacier, one 45 feet high was then constructed. Ice-dams in spring from the melting of the winter ice are common now-a-days and often make great floods; but at that time there was not only an almost unlimited amount of ice, but also earth and stones in the ice to aid as packing.

Mill River was then a great stream. It had, as part of its tributaries, the Farmington River from its source in the high region of Western Massachusetts to Tariffville; for an ice-dam at Tariffville cut off this river's head with the most of its length, and transferred the whole to Mill River. It received also the upper waters of the Quinnipiac, in consequence of a similar dam along the sandstone gorge between Cheshire and Meriden. Mill River had consequently a very large drainage area in the season of the flood. Part of the evidence with regard to the height of the dam at Mt. Carmel consists in the level of the water below Cheshire as indicated by the height of the terraces; and part in the groovings and large excavations in the sandstone below the dam along the present course of the railroad at a considerable level above the bed of the present Mill River valley. The position of the railroad against the west side of the valley, and the form of the surface of the trap ridge west of the railroad-cut, show that the waters which made the grooves and trenches along the railroad were from the *west* end of the dam. They were those of a literal sluice-way.

The accompanying figure is a profile of the gap, with the height exaggerated only two times. It shows the position of Mill River; of the carriage road at N; and of the railroad cut at R; and the form of the surface above the cut at HC. By ascending to the summit at HC, the height of the dam indi-

cated by the dotted line will be appreciated, and the fact that the waters would have overflowed at H; and there, at a height of 164 feet above tide level, began the sluice-way. Stratified gravel, deposited by the torrent under the lee of this ledge (visible from the railroad cut R) has a height of about 152 feet; and the upper limit now visible of the excavated trough or sluice-way near the Mt. Carmel railroad station, half a mile south of the gap, has a height of 145 feet. This trough or sluice-way in the sandstone was uncovered in grading for a new lay-out of the railroad, it offering the needed level for the track. It may be traced along the course of the railroad for 200 yards below the station; it then passes to the westward of the road and becomes the head of a partly cobble-stone paved valley whose stream—which may be called Sluice-way Brook (Plate I), joins Mill River below Centerville. The first part of the course



Profile of the Mt. Carmel village gap. R, railroad cut.

is marked by multitudes of bowlders on the west side of the railroad below the cut, all of them beautifully smoothed, but *not scratched*, because of the scouring they had from the gravel-bearing waters.

The junction of Sluice-way Brook and Mill River is shown with all the details here described in the Bache chart. Below Centerville, where the stream left its own valley to join Mill River, its course is marked by great accumulations of stones, and also, by a large cluster of "Kettle-holes." The kettle-holes may be best seen by going across the region, along the road just south of Sluice-way Brook. It is a strange place. Some of the kettle holes have a depth of 40 feet and a marsh at bottom on a level with the river. None open into the river channel; instead the margins of the kettle holes are 60 to 80 feet above the river.

Mill River valley bears evidence that the river was one of great magnitude and velocity in the beds of cobble-stone gravel to be seen along its course through Whitneyville. The cobble-stones which have been gathered on its western border on Orange Street for use in asphalt pavements are from deposits then made by the flooded river.

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10. To Meriden and the Hanging Hills.

For an afternoon excursion to Meriden, distant 19 miles, the cars may be taken at twelve or one. The Hanging Hills are 10 miles east-of-north of Mt. Carmel and $1\frac{1}{2}$ to $2\frac{1}{2}$ miles northwest of Meriden (see map, p. 44). They are trap mountains, remarkable for their steep declivities and high precipitous brows, which give to the observer beneath them an impression of over-hanging, and hence the name. Three "Hills" stand together on a common line, West Mountain, South Mountain, and Cat Hole Mountain. West Mountain has three summits, an eastern, a middle, and a western, separated from one another by a cut down to the lower limit of the mural rocks. The western of the three peaks is the highest; Prof. Guyot made it 995 feet above the sea.

To reach West Mountain from Meriden go westward along Main street, and its continuation the Waterbury turnpike (passing Fenn's millpond north of the road two-thirds of a mile on, and, immediately afterward, crossing a road that leads northward to Cat Hole gap and Kensington); at the forking, $1\frac{1}{4}$ m. out, keep to the right, taking what is called the Southington road, and continue on it about $1\frac{1}{2}$ m. farther (passing, half way, a road going north to the "Notch" between South Mountain and West Mountain); and when seemingly a little beyond the sought-for mountain, and just after a descent begins in the road, a carriage-path will be seen on the right (north) entering the woods, showing by its stripes of green that it is not much used; after half a mile or more upon this path, gradually ascending most of the way, an open spot is reached where the carriage way ends and the climb begins.

Along the road thus far glimpses are had of Meriden, and the eastern hills, of Mt. Carmel to the south, and finally of the

Cheshire and Southington region and the heights to the west. A prettily wooded bank with a streamlet at its foot follows part of the way the south side of the Southington road. After passing two or three millponds to the north of the road, another, large enough to be called a lake, and none the less beautiful that it is artificiai, is seen lying among the forests. Nearly all the way the Hanging Hills are in full sight, grand in all their varying aspects. In many places along the mural fronts great columnar masses stand out, clinging only by a single side, owing to the fall of the rocks underneath, and appearing as if just ready to go crashing down the mountain. But they hold on firmly, for the work of destruction in these trappean structures is slow. The long slope which rises at a large angle to hundreds of feet, and bears far aloft the grand lines of battlements, is, to a great depth, made of the stones that have fallen from the heights.

A path leads up to the summit. The first part of the summit which comes into view is made up, at its lower portion in front, of small columns, hardly longer or larger than a man's leg, that are gradually falling apart and adding thus to the debris. This small-columnar structure characterizes many parts of the Meriden Hills, and, as a consequence, the long slopes of fallen fragments often consist of such pieces of rock—some flat, but generally of irregularly polygonal shapes. Nowhere about the Meriden heights are large regular columns to be seen. This seems remarkable, considering the extent of the trap eruptions. Much of the trap breaks with broad vertical surfaces like Pine Rock and West Rock, and somewhat less plainly, East Rock. Just above the point referred to, and farther on along the gorge, the trap stands up in long perpendicular walls arising from vertical courses of fracture. The immense blocks of trap that roughly pave the bottom of the gorge remind one who is familiar with the New Haven region of the great trap bowlders on its western hills. They have the same fine-grained texture, and are often tabular in form, and laminated in structure.

The rock of the summit is fine-grained trap, or the *crust rock*, as it is well called, like that of the great bowlders of the New Haven region; but below, as may be observed on the way up, it is coarse in grain like the East Rock stone. (The crust rock

is not so named because separable from that below, but from its being the original exterior of the ejected trap, as proved by its fine texture.) The presence of the crust-rock at the top shows that but little of the height of the ridge was worn away by the old glacier as it moved over these summits. In fact, nothing else could be expected; for along this meridian there were probably few stones in the ice at a level high enough to over-ride or abrade the summit. There are no peaks in the valley to the north as high as this Meriden mountain, either in Connecticut or Massachusetts, except Mount Tom and Mt. Holyoke; and stones taken from lower heights would not have risen in the glacier against gravity to a higher level, except through a combination of circumstances in the slopes that should favor an up-hill push of the ice; and the circumstances about this West mountain do not appear to have been favorable for an upward movement of this kind. The Mount Tom bowlders would have made a narrow line, and would have had but little chance of leaving their mark, or much of their freight, on this high Meriden Station.

Over the bare trap surface of the summit, there are slightly raised lines dividing it into polygonal areas, which indicate that the rock beneath has a somewhat columnar structure. These lines are prominent because of the greater hardness of the rock along them, the intervening surface yielding most easily to the elements. This hardness is due to the filling of thin fissures with silica or some siliceous mineral; and the fissures were a result of the contraction of the rock at the time of its original cooling.

The long lines of fracture or open seams which intersect the surface are the courses of the *joints*, on which the laminated character of the rock (or its tendency to break into slabs and tabular masses) depends.

The view from the top of West Mountain is remarkable rather for its wide panoramic range than for grandeur of detail. In the landscape a wide undulating surface, seemingly almost a level plain, stretches from Berlin and Meriden, *southward* over Wallingford and North Haven, *westward* over Cheshire, and thence *northward* over Southington into Bristol; and the villages of these townships lie among great patches of forests, meadows and variously cultivated fields. On the east stands the long range of trap ridges from Mount Lamentation to Saltonstall Ridge in East

Haven. Farther south, are seen the Sound, and Long Island. More to the west, are Mount Carmel, 936 feet above tide level and over its flank, a part of the East Rock range, a spire in Fair Haven, and the old Light House on New Haven Bay.

To the southwestward, the northern part of the long West Rock range stretches on between Cheshire and Prospect, then bends a little eastward, and soon after loses itself in the open country of southern Southington, west of the Meriden Heights; for here the range terminates, about 17 miles from its commencement at Westville. Over and beyond these trap hills to the west, and also to the northwest, lies the elevated Woodbridge plateau, a region of crystalline or metamorphic rocks, attaining its greatest altitude in the towns of Prospect and Wolcott, and thence, declining toward Bristol. Still farther northwest, over Wolcott and Bristol, there are the heights beyond the Naugatuck, and the more remote and but faintly discerned Taconic Mountains of the Green Mountain Range. Among the summits on the western horizon, one quite prominent, called Great Mountain, belongs to the country beyond the Housatonic not far from the State boundary—Mt. Washington.

Turning to the northward, other trap hills come into view in a long range, terminating in Mt. Tom and Mt. Holyoke. The nearer, with rampant western front, are the hills overlooking Southington and Farmington; farther on is Talcott Mountain, on the western border of the town of Hartford. The ridges of Simsbury and Granby rise beyond, but they are not separately distinguishable, as they are seen only in profile. Mt. Tom shows itself, over what appears to be a low western extension of Talcott mountain, as a round-topped peak, steepest on its western side. To the right is Mt. Holyoke, (on the other side of the Connecticut); and still farther east are other summits of the Holyoke ridge. It is of interest here to remember what has been already stated, that these trap hills make one grand curving range, nearly 60 miles long, from West Mountain in Meriden to Mount Tom, and thence, bending easterly, to Mount Holyoke.

Many villages give life to the landscape. North of Meriden there are Berlin bearing northeast, New Britain north-northeast, Kensington, Percival's birth-place, south of New Britain, N. 30° E.; south of Meriden, Hanover or South Meriden, near a large

pond at the bend in the Quinnipiac, bearing S. 15° E.; Yalesville, more distant, in nearly the same direction, and beyond Yalesville, the much larger village of Wallingford ; in the valley to the west, Bristol, bearing N. 52° W., Southington, N. 30° W., Cheshire, S. 30° W. ; over the Woodbridge plateau, Wolcott N. 58° W., and Prospect, on the summit against the horizon, S. 60° W.

Crossing the summit eastward, a good walker may descend the long and steep slope of trap debris into the Reservoir gorge. For the drive it is necessary to go around by the road. The Reservoir is really a lake ; and lying amid forest-covered slopes in this mountain defile, overlooked by and reflecting the grand old walls that crown the heights, it is a scene of beauty seldom surpassed.

From the entrance to the gorge a path leads by the foot of the Hanging Hills westward to the Cold Spring gorge, near the Poorhouse. This spot is remarkable for the great bowlders which here lie piled together ; and also for the cold water that comes up from a deep recess between the huge masses of trap, in which ice usually keeps the year around, the shade and shelter making the spot a natural ice-house. Professor Silliman gives one of the earliest published accounts of the place in vol. iv, page 17, of the *American Journal of Science*, after a visit on July 23d, 1821. He carried off with him to New Haven a mass of the ice weighing several pounds.

The grand pile of rocks at the bottom derived from the heights above, the long steep slope of fallen fragments down which they made their descent, and the mural heights almost overhead seemingly ready for other avalanches, produce an impression of power and sublimity that is seldom an effect of simply motionless rocks. But here every object in the scene suggests motion and violence. Yet the blocks, gray and green with the vegetation over them, look as if they had lain quietly in their places for ages. The work of destruction above is, however, going slowly forward, and though a long period may intervene, other descents are sure to occur. A long, one-storied stone house stands just within the entrance of the gorge, which is made of thin columnar pieces of trap three to four feet long, so laid that the ends project very unequally. The queer porcupine-structure was erected for a ten-pin alley, as an appendage to the "Cold Spring House" (a Water-Cure establishment

that formerly occupied what is now the Poorhouse). If it does not, in the mean time, go to pieces by natural decay, it may yet feel the weight of one of the descending 1000-ton masses. Should this happen, *a strike* would be made beyond any former experience of the ten-pin alley. The place also has its shady ways and rock retreats, beautiful with their moss-covered walls, shelves of ferns or flowers, and over-shadowing trees, which may give much enjoyment in the exploration.

The trap on the east side of the gorge near the path (and in many other places about the base of the mountains) is for the most part amygdaloidal; and below the rusty, decomposed, crumbling exterior, the cavities contain commonly calcite, sometimes crystallized quartz, and now and then amethyst and agate.

The distance back to the Meriden railroad station from this place is about 2 miles; from the reservoir in the notch 3 miles; and from the place of ascent of West Mountain, a little over 3½ miles. This is one of several interesting excursions that might be made about Meriden.

About the mill pond to the southwest of Meriden abundant evidence will be found of the feebleness of the Quinnipiac River at the time of the glacial flood. The low terrace is hardly a fifth of that at Cheshire. The deposits are sand and fine gravel, not coarse gravel and stones. The desert-like sandy surface between Wallingford and North Haven is a consequence of the comparative feebleness of the stream.

11. To Roaring Brook—A Drive or a Long Walk.

Roaring Brook flows in a deep gorge in the West Rock Ridge about 11½ miles north of New Haven, but by the road about 14 miles. It is 2½ miles from the Cheshire station on the Canal railroad, and 1½ miles from Brooks' Station. The latter is not a station now unless the party to the gorge is large. To find the gorge from Brooks' Station, follow the road that leads west and then north for nearly 1¼ m. to a point where it crosses a brook, and where another road commences on the right by crossing the same brook; here turn and continue on for half a mile to bars,

beyond which is a wagon path. This path leads directly to the gorge, passing a saw-mill on the way. Farther to the right (north) there is a deep notch in the trap ridge, but the notch of the brook is a comparatively slight one.

The gorge is a deep cut into the heart of the mountain. At the principal fall, about half a mile up, the water descends about 60 feet in three falls, half of it in the first, and when the stream is full it is all one cascade. But a mill pond above uses up much of the water and now it seldom roars. There is much to enjoy in the way of scenery along the gorge ; and by climbing the summit to the south, covered with pines, a fine distant view is to be had. It will also be observed from the summit that there is no valley like that of West River between the trap range and the region of crystalline rocks of the town of Prospect on the west. The Arbutus grows abundantly along the way. In the bottom of the gorge at a spot nearly up to the falls the mineral datolite has been obtained in fine crystallizations by blasting into a vein.

12. To West Rock and the Judges' Cave—A Walk or Drive.

The best route to West Rock is by Whalley Avenue and Blake Street, or by Goffe and Blake Streets, to the east point of the Rock ; thence westward to the low extension of the trap ridge which makes the head of the first quarry, on the west side of which the path commences. The place may be reached from Westville by Pearl Street (the first west of the Post Office) and, after crossing the bridge, the third street going north; or else, if on foot, the first to the foot of the slope, and then following the path along the foot of the slope eastward. The ridge along which the ascent is made has been much narrowed by quarrying, but there is still little difficulty in following it to the summit.

On the ascent, at a height between 300 and 310 feet, going eastward a short distance, there is a fine view to the east and south ; the Triangle and the bare wall of trap facing it are in the foreground.

The summit surveying station has a height on the Bache map of 399 feet.* In the fine view southward the West River valley —which is tidal to Westville—is a prominent feature; but it has lost some of its charm now that the meandering stream has been turned into a straight canal for the benefit of the grass of the meadows.

A path goes along the top of the Rock westward, and by it the Judges' Cave may be reached in 12 to 15 minutes—the distance being about 1000 yards. The great masses of trap which lie together and make all there is of a cave, were probably united when the bowlder left the glacier. The breaking has come mainly from the growth of trees. The position is a little below the top of the ridge; and it is thereby evident that the journeying bowlder was at too low a level in the glacier to clear the summit. Were it not for this, it might have been carried on to join the large bowlders on the grounds of Donald G. Mitchell. The rock is fine-grained and much rifted, quite unlike that of the trap surface beneath it, and like the crust-rock of the Meriden Hills.

The cave is a poor place for shelter. But here at intervals in the summer of 1661 two officers of the Cromwellian army, members of Parliament and signers of the death-warrant of King Charles I, found shelter and protection from the royal pursuers who came in search of them soon after the Restoration. These refugees, familiarly known to the colonists of their time as "the Colonels," were Edward Whalley, and his son-in-law, William Goffe. Whalley died at Hadley, Mass., about 1678, and Goffe at either Hartford or New Haven, in 1680. Colonel John Dixwell, another of the so-called "regicides," came to New Haven about 1670, and died there in 1689. His monument stands on the public square behind the Center Church.

The descent from the cave may be made along a path leading down eastward to a short east-and-west road, and thence into the

* Prof. W. H. Brewer made the first barometric measurement of West Rock, November 13, 1866. He found the height of the summit near the front 393 feet, and a spot a little farther north a few feet higher. In making this measurement. Prof. Brewer had the misfortune to break his barometer—one that he had carried for years without accident over the peaks of the Sierra Nevada in California, 12,000 feet and more in height. The next year after this mishap a quicksilver mine was discovered on West Rock!

main road at the east foot of the Rock, and joining the latter at a point near a bridge over Wilmot Brook. The route across the bridge is the shortest way to the city.

On the way down from the cave, large masses of the granite-like rock, gneiss, may be observed. Many such occur along the eastern slope of West Rock Ridge, and all came from the Naugatuck Valley or beyond, as already explained.

West Rock may also be ascended by the path, just mentioned, to the Judges' Cave; and, for wheels, a carriage road to the Cave from the vicinity of the Almshouse, has been begun.

Another good route is by the path from the eastern foot of the ridge, just north of the Triangle. On Plate VI two paths ascend together; the north one has been made under the direction of the Park Commissioners, the commencement of a wide walk to the Judges' Cave. Just north of its commencement "Wet Run" descends, and a good drink of water may be obtained at the roadside. It is a *wet run* because the bed is in sandstone. To the south is "Dry Run," a good bed for a stream, but usually dry, because it is of trap, a rock abounding in fissures. If the purpose is to go directly to the summit of the Rock, and not to the Judges' Cave, keep on the old path as far as it is distinct, and then go directly west. Above a level of 300 feet the surface is of trap; but the slopes are easy of ascent to the path near the western brow.

13. To the South Front of West Rock and the Judges' Notch—A Walk, and for part of the way a Drive.

The south front of West Rock, a portion of which is represented on Plate VII, is visible in part from the road before arriving at Westville, but best in Westville from the top of the terrace at the north end of the street (Franklin St.) just west of the Westville School House. The cars pass the street, and wheels may go to the spot. When taking the view, it must be in mind that the trap came up melted along a line to the eastward, and flowed westward over the ledges of upturned sandstone (p. 30).

To reach the quarry road at the foot of the section, which is 90 to 100 feet above tide-level, cross West River by the Pearl

St. bridge, take the first left hand road to the foot of the mountain, then go eastward to a small shed, whence a path leads up to the road. First see a piece of the evidence that the trap came up to the eastward in a large outcrop just north of the "shed" at the foot of the mountain; it is nearly 60 feet below the level of the outcrop of sandstone beneath trap on the road above. The quarry road is easily reached by wheels, by continuing on Pearl Street to the third road going north.

The absence of distinct columns in the precipitous front is a point to be observed; and, instead, very distinct planes of division or joints in the trap conforming in direction to the face of the Rock, though with considerable variation; and also another less prominent transverse system of joints. The direction of the face-joints is about N. 80° W., becoming N. 70° W. farther west; and their northward inclination is 15° to 18°. Further, there is a remarkable twist in the face-joints over the eastward-dipping sandstone, they veering around so as to have the direction very nearly of the strike of the sandstone between N. and N. 10° W.; the more prominent joints thus changing places with the transverse.

The outcrops of the sandstone farther west have been enlarged somewhat since the photograph of Plate VII was taken. It will be seen that the crumbling purplish layer becomes darker above; and that portions of a red layer at bottom are in sight. The junction line of the trap and sandstone is in most parts accessible to an enterprising climber. The quarry road continues for 200 yards beyond the part represented in Plate VII, and other outcrops of sandstone come successively into view.

On page 31 the conclusion is drawn that the outflow of trap was a flow under a cover of sandstone and not an outside flow. But the point should have further investigation. If on the examination of the junction-plane of the trap and sandstone here and elsewhere in the Connecticut valley there should be found between them a bed of earth, gravel, or stones not of possible derivation from the trap or sandstone, or relics of terrestrial life of any kind, or any water channels or other evidences that the surface of the sandstone had been a region open to the air, the evidence would be adverse to the conclusion. On the contrary, it would be favorable to it if only angular fragments of sandstone, which

the onward shove of the flowing lava might make, are found, or rounded masses of sandstone or trap, isolated or in beds, such as might be formed underneath the heavily flowing mass.

In order to reach the Judges' Notch from the end of the quarry road, descend to the road of the valley; or if the bank of the river is reached, continue on it northward to the road and a bridge; then follow the road northward to the first white house, and there take the path northeastward through the partly shaded fields to the Judges' Notch. An eastward path goes off up the notch soon after passing the dry (or wet) bed of a brook. On the ascent, coarse sandstone may be observed a short distance below the trap. On arriving at the summit, which is about 360 feet high, the Judges' Cave will be found a short distance to the southeast.

From the cave the descent may be that of the preceding excursion. But an interesting and untrodden route is as follows: To the surveying station at 399; thence down to 300, at the head of the Triangle; here northward to the top of the bare wall of trap facing the Triangle, and into the trough adjoining. (Plate VI). This route ends in the Triangle behind the second house.

14. To Wintergreen Lake—A Walk or Drive.

The road passing the east point of West Rock continues on beyond the Almshouse, going by its west side, and nearly a mile north reaches the foot of the little trap ridge which bounds Wintergreen Lake on its south side, and also the border of a small flow of water which has served at many picnics. A path ascends the ridge to the lake.

The carriage road turns eastward and makes a rather steep ascent out of the valley, and affords one way of returning to town. After making this ascent the pedestrian may take the road near by going directly east, and thus make his way toward Dixwell Avenue and the city. But this road is a steep one for wheels; the one next north is much better.

A more interesting route home for the pedestrian is through the woods up West Rock Ridge to Wintergreen Notch, and thence down to West River valley and Westville. There is a fine exhibition of trap columns north of the path on the descent.

The trap along the south side of Wintergreen Lake is the eastern extremity of the "Buttress dike." It differs from the trap of West Rock in containing whitish spots every 3 or 4 inches, which are due to imbedded crystals of the feldspar anorthite ; and with a hammer in hand this porphyritic character may be used for tracing the dike across the West Rock Ridge.

15. To the Buttress Dike—A Walk.

Buttress dike is the only one of the kind yet known in the Connecticut valley, that is, the only one that cuts through one of the large trap ridges and thus shows that it was ejected after the trap it intersects had cooled. It has therefore special geological interest. Besides this, there are pleasurable difficulties and risks in the ascent. Moreover, it affords on the way up gradually changing views of the whole West River valley from far north to the Sound, which increase in interest with each new stage of elevation ; and when Buttress Peak is finally reached, the addition to the view, at last, of the New Haven plain, with West Rock to the south in the foreground, is a surprise that adds much to the gratification.

At Westville, take the road up West River valley and continue on it beyond the Pond Lily Paper Mill. A bridge not far on affords a chance to cross the river on the way either to Wintergreen Notch, or to the Buttress dike which is not far north of the road to the notch. There is also a bridge across the river nearly in a line with the dike. The Buttress projects from the steep front of West Rock, and, before the leaving out in spring, is visible from the road. Later it is a mass of foliage to the bottom, between slopes of West Rock debris. It consists of solid columnar trap ; and the columns, as may be seen on the ascent, have a pitch southward. Two-thirds of the way up, there is a chance to go along the northern wall of the dike to the place where it cuts through the West Rock trap, and with a hammer to observe the difference between the rocks of the two. From this point the adventurous climber may make his way in a corner up the steep front to the summit, while the more prudent will return to the dike and follow its rough course. At the

summit the dike is traceable only by means of a hammer; but farther down the eastern slope it stands above the surface as a bold ridge; and from there it may be easily followed to the southern border of Wintergreen Lake.

A plotting of the route followed along the dike from West River valley over the summit to the lake would show a very large bend in the course of the dike. But this bend in a plotting is owing to the inclination of the dike southward of about 25° and to the height of the Rock, about 450 feet, or 350 above the West River plain at the western base; this height and angle giving the dike at the summit a southward throw of more than 150 feet. Shaved off to a level plane the actual course of the dike would be found to be straight, and about N. 35° E.

Continuing along the border of the lake on the dike, its end is reached in about 300 yards. Here the dam is in sight to which the lake owes its existence.

To find Wintergreen Gorge and Falls, go southward by the road for about 500 yards; then turn eastward to a branch of Wilmot Brook, the stream that flows from the lake; and in the course of a few rods the gorge and falls will be reached. It was a place of much beauty before the lake used up the water; and it is so now after heavy rains. The best point of view is from a high rock, at the summit of the gorge, below the falls, some distance east of a dwelling house.

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16. Through Western Hamden, the southern Bethany Notch in West Rock Ridge and West River Valley—A Drive or a Long Walk.

This highly interesting drive passes in sight of West Rock on its eastern or more sloping side, crosses the narrow notch (n^3, Plate I) westward, and then returns in West River valley along the western or palisade side of the ridge. The best route for fine views is by Dixwell Avenue to Arch Street (2 m.); along Arch Street across the northeast end of the Beaver Pond Meadows, and then bending northward, passing between the main body of Pine Rock (C C′, Plate I) and the eastern outlier (D); and thence northward to the second road crossing; here turn north-

westward and keep on westward to the road nearest the foot of West Rock Ridge and follow this road to the Notch. The height of the Notch before beginning the descent (according to the Bache map) is 500 feet, and of West Rock in the vicinity, 650 to 700 feet. Passing the Notch, the route is a nearly straight one down the valley to Westville. Before passing the Notch the ascent of a high trap peak—*Wn*, Plate I (called Warner's Rock, height 610, Bache) will have its reward in a grand view southward and southeastward.

The distance from New Haven is 3 m. to the Pine Rock gap; and, including this, 8 m. to the Notch; thence southward 7 m. to Westville.

17. To Sargent's River, the Cement-works, and Woodbridge—A Walk or Drive.

Sargent's River is about 4 miles from Westville. There are fine views of the West Rock palisades all along the way; and nearing Sargent's River, the large lake, made for water-supply to the city, adds to the beauty of the region. The rock passed on the latter part of the way is a poor variety of roofing slate, called in geology hydromica schist. The slate stands at a high angle, and at places contains quartz veins.

The lime-kiln of the cement-works is in full view at Sargent's River. A path leads to the quarry from which the limestone for burning was obtained. The limestone in the quarry stands at a high angle between layers of the hydromica schist. The most of it contains minute, brilliant cubes of pyrite, and is also impure from the presence of much mica in fine scales. Owing to the pyrite (a compound of iron and sulphur) the limestone decomposes very easily, leaving behind a thick, dark brown, earthy crust resulting from the decomposition of the mica with some of the hydrous iron oxide, limonite, due to the oxidation of the iron in the pyrite.

A true cement-rock is a limestone impure from the presence of clay. An analysis proved that the chemical constitution was essentially that of a good cement-rock. But it turned out, after much money had been spent, that, inasmuch as the impurity was

mica, the limestone ran into a slag instead of burning properly to lime; and then, after meeting this difficulty by using less heat, that the lime obtained was good for nothing for making cement (a mortar that will set under water).

The road going west by the north side of Sargent's River passes through Sargent's Glen. The drive south through Woodbridge is very enjoyable on account of its fine views.

On the return, the rock along the way will be found to be the slate, hydromica schist, until a cross-road is reached, near a small factory, about three-fourths of a mile from the junction with the valley road. At this point the hydromica schist is the rock of the hills some distance west of the road; but the road there is a greenish rock, called—from the greenish mineral, chlorite, which it contains, chloritic hydromica schist. This greenish rock continues southward all the way to Savin Rock. At this place in West River valley it narrows out and disappears beneath the alluvium of the valley, heading obliquely toward the West Rock ridge. It is a western portion of a small anticline, having N. 38° E. as its direction or strike.

18. By West River Valley to the Second Bethany Notch and back by the "West Woods Road" through Hamden—A Drive.

Take the road up West River valley to the southern Bethany Notch (n^3, Plate I); but instead of crossing at this notch, continue northward half a mile to the next notch (n^2), which has scenery to enjoy. Here go eastward first by the south side of a brook; then turning northward where a road comes in, cross the brook; then take the first road to the right or eastward and again cross the brook just after passing a road going north; thence eastward to the second road going south, which is the West Woods road; the distance from the Notch is nearly 2 miles. The northern part of this drive is through forests—a wild woods drive. In 3 miles the road joins Dixwell Avenue by the side of Sluiceway Brook in the vicinity of Augurville, 2½ miles north of Whitneyville. The whole distance around from New Haven is about 20 miles.

19. Woodbridge Heights and the Great Bowlder—A Walk or Drive.

Reaching Westville go west on Fountain Street. The first rise in the road is to the top of the West River terrace—the western part of the New Haven plain, which is about 60 feet above the level of the river. The gravel which underlies it is largely of the cobblestone kind; for the glacial flood came down West River valley with great violence, making a fall of 80 feet a mile from Bethany. By the Westville cars this ascent is made on Main Street, and then by a cross street, Fountain Street is reached. Soon the street takes another rise—that over the low northern part of the Edgewood Ridge—a ridge on which "Edgewood," the estate of Donald Mitchell, is situated. The road next crosses the broad Maltby Park valley, so named from Maltby Park, which lies in it a mile to the south. A lake occupies the breadth of the valley 150 yards to the north of the road; but great ice-houses injure the view. A little over a mile from Westville the ascent of the "long hill" or the Woodbridge Heights commences and while on the way up, the following explanations are in place.

Maltby Park valley and its bordering ridges make the western border of the New Haven region from here southward to Savin Rock on the Sound, and have a common geological history. The valley and Edgewood Ridge disappear, half a mile to the north, in West River valley. Two miles north the ridge of Woodbridge Heights also ends in the valley; its course is here N. 38° E., while that of the adjoining part of the valley and of West Rock Ridge is nearly north and south. Southward Maltby Park valley becomes the valley of Cove River, which enters the Sound a mile west of Savin Rock.

Geologically, the valley and the confining ridges are the course of a great upward bend in the rocks, or an anticline, a result of a mountain-making movement in Paleozoic time or earlier; and thus it is that they have a common origin. Like most anticlines the stretching of the rocks in the bending occasioned large and deep fractures along the summit of the arch, and this led to degradation through the waters of the sea and rivers, producing the valley and its many ledges.

The summit of the "long hill" is reached on passing the Clinton cottage. North of the road, 140 yards below the cottage, a path goes from the road northward; and within 100 yards a high summit west of it affords a fine view, in which West Rock is projected on East Rock. Just west of the Clinton cottage a high crag of abrupt sides overlooks the leafy Maltby Park valley with its lake, the Edgewood Ridge, and beyond these the city and country over a wide range; but the view, a few years since one of the best in the whole circuit of New Haven, is now obstructed by a new growth of trees; and another cutting of the forest must be waited for before the Clinton Crag will repay for the climb. On the same line half a mile south another high crag has afforded a similar view still more panoramic. A wagon-path, starting just below the cottage, leads southward to the ledge. (In following it be careful, when nearly half way, not to turn off by a branch path to the westward.)

The high points along the crest of the eastern Woodbridge Ridge are good places for a geological thought—that during the Jura-Trias period, when the Red Sandstone was forming in the wide Connecticut valley estuary (see page 00), this Woodbridge region was a part of the western shore of the estuary. The rock of the region is the chloritic hydromica schist, already mentioned. It here stands nearly vertical, the dip of the beds being westward 70° to 80° and 90°.

One hundred yards west of the Clinton cottage, north of the road, the Buttress trap-dike rises above the surface with a vertical eastern front—being thus prominent because more enduring than the slates either side. A hard blow with a hammer will suffice to obtain evidence that the rock is not the slate or schist, but true trap, much like that of West Rock. There are good views to be had from the top of the dike. But the best, and one especially charming, requires a walk in the direction of the dike eastward (N. 35° E.) to its highest point (about half a mile from the road) where it overlooks West River valley. It adds this valley to the New Haven prospect and includes a near view of West Rock; and through Wintergreen Notch appears, in the distance, Tremont, of the Durham trap ridges. There is a difficulty in the walk; for the dike in places disappears beneath the surface. The best route to the lookout is by the path going northward and east-

ward, 140 yards below the Clinton cottage; it leaves the road near a tub for watering horses. The path, where obscure, is marked by red tags; it leads directly to the extremity of the dike overlooking West River valley—360 feet above high tide according to the Bache chart.

When there, the great 1200-ton bowlder is only 200 yards off to the west of south. From the south side of the dike a line of red tags indicates the way. The region has recently become so overgrown that the great mass is visible but a few yards off, and the extended view from its top is narrowed to a mere cleft between the tree tops.

The trap-dike may be followed by taking one of the paths east of it; but they cross its course, and there is a risk of losing the way. A hammer may be needed to re-discover the dike.

Till recently a growing cedar had its roots in a cleft in the upper surface of the bowlder, threatening to break it in two. But a ring of the bark was taken out from the base of the trunk, and now, although the cedar still stands, it is dry, and the bowlder is safe from the disaster.

From here the way may be retraced to the road, and the drive or walk continued westward and, then by the first road northward, eastward and southward through Woodbridge to the West River valley and Westville—the distance around $4\frac{3}{4}$ miles. Or the return may be made by the pedestrian from the bowlder northward to the dike; thence across it, and northeastward to the east slope of the hill into the valley.

At the commencement of the descent there is a large bowlder of trap in two pieces, and a look off may be had from its top. Three others lie near by now concealed by the trees and shrubbery. Going northward an open field is reached, and over it the descent may be continued to the road at its foot. The great bowlders are lodged along these heights, about one mile (5000 to 5400 feet) west of that of the Judges' Cave, because, like that, combed out of the ice by the ledges of the summit.

Nearly a mile west of the Clinton cottage the road forks, one road going southwest to Derby and the other northwest to Seymour. At the forking the outcropping rock is that of the western margin of the chloritic hydromica schist; but along the west side of the outcrop a thin portion of the next rock in the series is

exposed to view, the hydromica schist; and here the boundary line passes between the two rocks. The chloritic schist contains epidote in some of its quartz seams.

From the point in the road reached in the descent above described, it is but a short distance north to the small old factory referred to at the close of Excursion 17, where the chloritic schist makes its disappearance. This place (about $1\frac{1}{2}$ miles from Westville) merits a careful examination in order to understand the fact there stated that the schist lies in an anticline; and the hill to the west should be ascended to ascertain that the next rock west is the hydromica schist. This being proved, another location of the boundary between the two rocks has been approximately ascertained; and others between the two are easily added.

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20. The Edgewood Walk or Drive.

From Westville go out Fountain Street half a mile and then turn southward down Forest Street. It passes the residence of Donald G. Mitchell, which will be recognized by the long line of evergreen hedge in front of it. The road rises above the foot of the western hills—the Edgewood Ridge—and affords many fine views to the eastward. Chapel Street terminates in Forest Street about a fourth of a mile from Derby Avenue. Abreast of its termination three large trap bowlders, one of them weighing at least 250 tons, may be seen by crossing the fence and going on southwestward for a few rods.

Forest Street crosses Derby Avenue, but to the south it is called Campbell Avenue. The drive may be continued southward along Campbell Avenue, which is much of the way shaded by trees, to Allingtown, and a return made by the Milford turnpike. The distance from Fountain Street to Derby Avenue is a little over a mile; to Allingtown, nearly 2 miles. If Derby Avenue is taken, the Yale Athletic Grounds, half a mile east, will be passed, and then a descent made to the level of the West River meadows and bridge. When passing the bridge it may be observed that each side of the river has its high terrace, and both at the same level, the terrace being that of the New Haven plain. The terraces have a height of 49 feet above mean tide. The position and height of the terrace-slopes along the river are shown on Plate I.

21. To Maltby Park—A Walk, or in part a Drive.

Out Chapel Street and Derby Avenue, passing West River, the Yale Athletic Grounds, and finally Forest Street. By the west side of this street is the summit of the Edgewood Ridge, the eastern boundary of Maltby Park valley, and a mile west are the Woodbridge Heights, its western boundary. Over the Park there are three lakes, a southeastern, northern and western, the first and third near the Derby road, and the other north of the first. These lakes were formed, under the direction and outlay of Mr. C. S. Maltby, who embraced in his project four other lakes that were never constructed. He had in view, besides the laying out of a park, the supply of the city with water. Toward the former purpose good roads were laid out in different directions which at several points led to high summits and extensive prospects. The Park grounds were offered to the City under certain restrictions, which were not accepted. Since then the New Haven Water Company has bought in the lakes. The roads, consequently, have been partly broken up and the summits overgrown, so that only pedestrians can enjoy it. Previous to the making of the lakes, the region was one of rocky ledges with small intervening valleys, forest-covered, and often marshy, and also of a quarry of serpentine-marble, which is now, to the misfortune of the mineralogist, mostly under water.

To go to the first lake, take a shaded path north of the Derby road, east of the stream; it passes near a large vein of quartz, and then rises to the lake border. The center of the lake once had its fountain. Take now the path by the east side of this lake and soon the northern lake will be in sight. Pass over the causeway by the south side of this northern lake and continue westward by a broken or partly obliterated path, and in a few minutes a north-and-south path will be reached; and going south along it, the western lake will be soon in sight. The path leads along the west side of this lake to Derby Avenue. Near the west angle of the Park on the north side of the Derby road, a path commences which ascends through the woods obliquely to an upper road; and just north of the point where it is reached, in an open field, the nearly vertical and westward dip of the chloritic schist may be examined and a fine prospect eastward enjoyed. The

landscape is to a great extent made up of the wooded slopes of the Edgewood line of hills : but, in the direction of the intersecting Derby turnpike, there is a deep downward bend in the profile, affording a distant prospect of nearly the whole city, the effect of which is exceedingly pleasing. One of the lakes of the Park forms part of the foreground.

Now for the rocks.

In the Edgewood Ridge, just west of Forest Street, and also over the Park, the chloritic hydromica schist is the rock. It is of interest first to ascertain from the Edgewood Ridge, the *eastern* margin of the Park, whether the dip corresponds to that of an anticline or arch across the Park area, or to a syncline. It will be found to be about 40° or 50° to the *eastward ;* indicating a rise westward and therefore an upward bend or anticline. Now the dip was *westward* on the Woodbridge Heights to the west of Westville, in general 70° to 80° W.: and it is the same west of Maltby Park. Putting the two together, they make an *upward* bend, pitching 40° to 50° eastward on the east side and 70° to 80° westward on the west side. This is part of the evidence that the region of the Maltby Park valley through its whole course to Savin Rock is that of an anticline. Over the interior of the Park there is much variation in the position of the beds, and it is probable that the anticline is a compound one.

On Derby Avenue, before reaching the ice-houses, outcrops of rock are numerous along the northern road side. Besides the slate, there is a blackish massive rock looking much like trap, and also for a short distance a dark gray limestone hardly crystalline. The limestone is arched up into a low *anticline* and this fact favors the conclusion just expressed.

The massive rock is one not often seen. It is a kind of dioryte —so called because it consists (as microscopically ascertained) of hornblende and a feldspar ; and it is named labradorite-dioryte, or labradioryte, because the feldspar is the species labradorite. Part of it is spotted with whitish crystals (or altered crystals) of labradorite, and is therefore a *porphyritic* variety of the rock. The crystals usually have lost their luster and cleavage and have probably the composition of the mineral saussurite.

Along the path by the east side of the first lake, about two-thirds of the way to the northern lake, a triangular ledge, about

12 feet high, of dark-colored partly greenish rock will be passed on the right which has been much hammered on account of the serpentine and serpentine marble which it contains; it is sometimes called "Serpentine Crag." Some asbestus (fibrous serpentine or chrysotile) may be found in it in thin seams. The rock was once quarried on its left or north side. About 125 yards beyond is the north lake. By going along the eastern side of this lake to its northwestern, a bluff will be found facing the lake, which, early in the century, was extensively quarried for serpentine marble, or verd-antique (a mixture of limestone and serpentine, when pure). Large slabs were obtained and polished, specimens of which may be seen in the Yale College Cabinet. The color is yellowish-green, clouded and banded with other shades of green, and further variegated with yellowish-white and black, the last from the presence of magnetite. But the rock proved to be so irregular in structure, and in many parts so impure, that good blocks were difficult to obtain, hard to saw, and troublesome to polish; and the quarry, not paying, was consequently abandoned. Some asbestus (chrysotile) may perhaps be found in the loose masses of rock along the north side of the lake, when the water is low; and on the west side of the bluff, where there is a small brook, some pyroxene.

A quarry of similar verd-antique marble occurs 2 miles east of Milford, near the turnpike. But it presented the same difficulties in polishing, though to a less degree and has not been worked for many years. The marble is very beautiful when polished, and differs from that of New Haven in its bluish instead of yellowish shade of green. This Milford quarry was the one first made known, it having been discovered in 1811 by Solomon Baldwin, then a student in the senior class at Yale, while out on a mineralogical excursion with Professor Silliman.

Much of the slate or schist of the Park will be found to be interlaminated with quartz; and at some places there are quartz veins. The veins and the interlaminations have essentially the same origin.

Passing the causeway south of the northern lake a place may be seen north of the path, shortly before reaching the north-and-south path above mentioned, where a quartz-vein was mined for copper ore. The expectant miner—it was soon after the Califor-

nia fever broke out—got nothing except some flattering specks of ore. A few rods north on the north-and-south path, a branch path goes eastward up to one of Mr. Maltby's lookouts. On the north side of the path near the top, there is another old mine in a quartz vein, and here two shafts were sunk 10 or 12 feet and much quartz thrown out, and, it is reported, that one piece of ore as large as the hand was obtained. The ore is the yellow chalcopyrite—of a gold-yellow color. Small pieces are now often found in the broken quartz, especially in the rusted pieces ; and besides the chalcopyrite, traces of malachite and azurite are met with and some pyrite. Pure chlorite is found in cavities in the quartz, as in other quartz veins of the park.

On the south shore of the western lake, between it and the Derby road there is another spot which was once worked for copper. In the many fragments of quartz about the spot, traces of copper ore, and also of the common lead ore, galena, are occasionally found.

The schist of the Park and its quartz veins and interlaminations are closely like those of a California gold region ; for gold, when in place, is usually found in quartz veins and often in a region of chloritic schists. But there is one important difference ; the gold is left out. A. C. Dill, of the class of 1840, carried 40 pounds of the quartz from the last-mentioned locality on his shoulder to the city for an examination of it for gold at the Sheffield laboratory—the occurrence of lead ore as well as copper ore and pyrite seeming to be favorable indications of its being true auriferous quartz. The trial was a complete success in proving that the gold was left out !

Returning by Derby Avenue, glacier scratches may be seen on the south side of the road before reaching the house at the former turnpike gate, and farther on also on the south side of the road. (See the following map.)

22. To Round Hill—A Walk or Drive.

Round Hill is another of the prominent points on the west, overlooking the city. Its position, and that of Maltby Park, Cove River and other places in the vicinity, are shown on the

accompanying map. Its height is about 304 feet. To reach it take either Congress or Davenport Avenue and continue west to

Map of Round Hill and vicinity, showing also the position of Maltby Park and its lakes; of Derby Avenue on the south side of the Park; Milford turnpike (Milford T.) south of Round Hill; the Derby railroad and its cut through Edgewood Ridge, east of Cove River; the New York and New Haven railroad, and its cut through a low part of the same ridge; the courses of glacier scratches indicated by arrows; and giving also heights above mean tide.

Allingtown on the Milford turnpike. Round Hill is the site of the residence of Mr. R. M. Burwell, and a good road leads to the

summit from a point just north of Congress Avenue. The hill, unlike the bordering region, over which rocky ledges of chloritic schist stand out too numerously, is without a ledge through the whole of the upper 120 feet. Mr. Burwell sunk a well into the gravel of the summit, but had to go down 107 feet to get water. It was all the way through hard-packed bowlder-clay or till. Round Hill is hence, not a hill of schist, but a high isolated pile made by the glacier. Another remarkable feature of the hill is the existence, 160 to 180 feet below the top, of a deep trench half way encircling it. This pile of till may have been made by deposition of earth and gravel from waters descending a crevasse in the glacier, and the trench by the denuding action of these waters.

The summit on the Milford turnpike above Allingtown also has its fine view. Moreover, along the sides of the road for half a mile west there are glacier scratches, as indicated by arrows on the map. There is also a large trap-bowlder on the north side. Near "140" on the turnpike (see map above) a path leads from the road to a spot north of it where another shaft was sunk years since for copper ore. Leaving this pit on the left, the strange trench referred to above, 50 or 60 feet deep, comes into view. Crossing the trench, Round Hill may be climbed.

At the summit above Allingtown, a hundred yards north of the turnpike, there is a monument to Adjutant Campbell of the British Army, who died at the attack on New Haven of July 5th, 1779. The British landed on West Haven point and in some skirmishing on Milford Hill, Campbell was shot. The only stone until recently was a fragment of trap, rough and unhewn, bearing the inscription, "Campbell 1779." It was put up by Mr. John W. Barber of this city in October, 1831, he doing the cutting on the spot. A new monument has just now been erected (1891).

23. To Savin Rock—A Walk or Drive.

The best route to Savin Rock for a drive or walk is from Congress Avenue out Washington Street and its continuation, Spring Street, to the north-and-south road at the foot of the hills called Campbell Avenue; thence southward, by Savin Avenue,

to Savin Rock. The drive may be continued westward across Cove River valley just west of Savin Rock, and thence another mile and a half along the coast to Woodmont; thence northward and eastward by the Milford turnpike to the city; or the return may be made by Savin Rock.

On reaching Campbell Avenue on the way out, the extensive (and expensive) Derby Railroad cut may be visited. The prevailing rock is the greenish chloritic hydromica schist or slate already mentioned; but at several points it graduates into the massive labradioryte. The latter rock, in hand specimens, looks like an igneous rock; but its relation to the slate shows that the two had the same kind of origin. Since it consists largely of the *lime*-feldspar, labradorite, it was probably formed from those portions of the mud of an ancient West Connecticut sea that contained much lime (from the presence of fossils?). It will be observed that the dip of the slate is small (about 25°) nearly northward.

On Campbell Avenue, at the house of J. Foote, situated high above the avenue, a finely glaciated knoll of rock will be found by the north side of the house; the rocky knoll is a beautiful example of what Agassiz named "Roches moutonnés" (Sheepbacks). Along the track of the N. Y. & N. H. Railroad, the same facts with regard to the rocks may be seen as in the Derby cut, though less perfectly displayed. At the railroad cut take the path going west and continue for 300 yards nearly to a north-and-south road; thence over the field south, where there has long been an exposure of rock finely glacier-marked, and another of the "roches montonnés" larger than that in Mr. Foote's yard, now, unfortunately, half buried under rubbish. The glacier, abrading by means of the stones in its bottom, wore down the schist easily, and left these scratched and polished knolls where the rock was harder than elsewhere. Many of the "sheep-backs" consist chiefly of the tough and hard labradioryte.

The interesting points to be observed at Savin Rock are the fine display of ripple-marks on the sand-flats off the shores when the tide is out; the abundance of blackish sand along the upper part of the beach, containing magnetic iron in grains and easily gathered by means of a magnet; the small, nearly northward dip of the slates; the many seams of quartz in the slates, in

some places interleaving it, as in Maltby Park; the regular system of joints or nearly vertical divisional planes in the rocks; the wearing away of the rocks by the action of the heavy seas; a bowlder of gneiss on the western part of the main point, and a large bowlder of trap farther to the southwest. The sand-flats should be looked at as illustrations of the most common method of making sandstones, with or without ripple-marks, through all geological time.

A study of the position of the slate, that is, its dip and strike, at Savin Rock, in the two railroad cuts and at Maltby Park, sustains the conclusion that the whole region from Savin Rock northward is the course of an anticline; and the small northward dip—about 25°—along the center of the region is further evidence that the axis or ridge-line of the anticline has a pitch northward of about 25°.

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24. To Beacon Hill, and the East Haven Trap-dikes and Bowlder—A Walk or Drive.

For the walk, the best and shortest way is by Tomlinson's Bridge and Forbes Avenue to Townsend Avenue a mile from the bridge. But carriages usually avoid the tangle of railroad tracks about Bridge street by continuing on Chapel Street to Ferry Street in Fair Haven, and then crossing the bridge southward to Meadow Street, where East Ferry Street (or the first road eastward) may be taken to Forbes Avenue.

Over half a mile from Tomlinson's Bridge, the road has a bluff of sandstone 120 yards long on its north side, and in it 8 or 9 small trap-dikes may be counted. They vary from 4 inches in width to 8 feet or more, and have various directions and shapes. Five are 6 to 8 feet wide. One is 3 feet wide near the bottom, but rapidly narrows, and tapers out in a thread bent eastward between the layers. The sandstone beneath the road if uncovered would present an interesting display of this knot of dikes. In the short outcrop on the south side of the avenue only one of the dikes is to be found. The sandstone is for the most part grayish white from a discharge of the red color by the heat of the melted rock. A few layers of coarse conglomerate occur

in the sandstone, and some of the rounded stones are 10 inches or so across.

On the first road going south beyond the sandstone, named Woodward Avenue, in the yard connected with the first house that stands far back from the road, there is one of the most interesting bowlders of trap in the New Haven region. It is a rare ornament for a door yard. It is 11 feet long and 6 high, and weighs over 30 tons. It rests with its smaller side downward on a projecting ledge of coarse sandstone ; and it is quite prominent above the surface around because the rock directly beneath it was thereby protected from the sun and rains. A score of years since, the sandstone under it had groovings that were made by the mass before it came to complete rest ; and their direction was S. 5° W. Where it got aboard the glacier it is not easy to decide. The trap is precisely like that of the Judge's Cave. Mr. Dodd, in his history of East Haven, mentions this mass and the markings beneath it, and asks whether it is not of Celtic origin. The monument with the inscription dates far back of any American Celts.

Beacon Hill is the high rounded elevation on the east side of Townsend Avenue. After going a fourth of a mile on this avenue, a road over the north flank of the hill may be taken, and from its highest part, the ascent may be made ; but at present only on foot—the layout of Beacon Hill Park being unaccomplished. The view from the summit differs from most of those of the New Haven region in the extent of its range along the Sound, and also in its wide East Haven landscape. The long ridge on the east extending far north under dark foliage, is Saltonstall ridge, on the west side of Lake Saltonstall. For the best landscape westward the time should be that of high tide. But that at low tide is interesting since it exhibits, as in a bird's eye view, the anatomy of the bay,—a narrow crooked channel between great mud flats, with a long curving sand-point projecting inward from the West Haven cape. The channel is that of the united Quinnipiac and Mill Rivers.

The summit affords so fine a prospect that it has been used as a place of lookout as well as defense from the earliest historical times; hence the name of Prospect Hill. According to tradition, the Indians had here a fort prior to the coming of the English,

and in view of this it was early named "Fort Hill." It was sometimes called also "Grave Hill," from the Indian burying-ground upon its slope. In 1775, at the beginning of the Revolutionary war, the town of New Haven (as appears by a public notice of that date), erected a beacon at this point, and arranged for giving the signal of alarm in case there should be danger of an enemy's attack, and thus the name "Beacon Hill" was introduced. Such an attack did come a few years later, when the British forces under Gen. Tryon landed simultaneously near South End on the east side of the harbor and near Savin Rock on the west. This was in July, 1779. A small fort then stood on the shore near the site of the present Fort Hale, and was called "Rock Fort" or "Black Rock Fort." It had but three guns and could not successfully resist the British approach. The night after the attack, Gen. Tryon held a position on Beacon Hill, "the heights above Rock Fort." On this same summit, during the war of 1812, earth works were thrown up for the defense of the harbor against the British, whose bombardment of Stonington and threatening approach to New Haven had justly alarmed the inhabitants. President Day, Professor Silliman and Mr. James A. Hillhouse were among those who took part in the construction. The fortification was known as Fort Wooster after Gen. David Wooster, an officer in the Revolution, whose home had been New Haven.

Beacon Hill consists mainly of sandstone, but a large trap-dike is the foundation upon which the old fort at the summit was built. The hills to the south are also of sandstone and trap.

25. To Morris Cove—A Drive or Walk.

Morris Cove, on the east side of the harbor, has its fine beach, and the way to it is along one of the best roads of the region, Townsend Avenue, with the Bay in sight through all its length. The Cove is about $2\frac{1}{4}$ miles from Tomlinson's Bridge, and the same nearly from the Fair Haven bridge. Along the higher part of the road the view north is the best land prospect on the route. A line of heights sweeps around from West Rock by Pine Rock

and Mill Rock to East Rock ; and Mount Carmel lies low on the horizon still farther east.

Less than half a mile from the Cove a road goes down to Fort Hale on the shore, connected with the proposed Fort Hale Park, which is continued southward to a long bluff of trap—the "palisades," and then returns to the avenue.

Fort Hale is a place of some historic interest. It was built in 1809 near the site of the older Rock Fort, and was named after Nathan Hale, a graduate of Yale College in 1773—a small round brick structure of no value in modern warfare. During the civil war, in view of danger from Confederate privateers, it was made a substantial fortification. The bold bluff of trap, south of the fort, makes the northern limit of the Cove. The rock is a less durable kind than that of East Rock, and consequently it is brown from decomposition at surface. But it is interesting to observe that the trap shows scarcely any sign of the decomposition below the level of high tide. The decay, which is due to the oxidation of the iron in the rock, requires the presence of air as well as moisture, and the tide hence fixes its limit.

Along Morris Cove, not far from the water, there is a terrace, made of stratified sand and gravel, having a height of about twenty feet above sea-level. Houses of the Cove range along it. A similar terrace exists on the opposite side of the harbor in West Haven, on the line of First Street. The two terraces thus confronting one another, were evidently made by water passing through the harbor into the Sound. The terrace is believed to indicate a former submergence of the coast region to a depth of 25 feet. The time is referred to the glacial flood, or that of the melting glacier. . At this time the St. Lawrence valley near Montreal had the sea over the land up to a level of 500 feet, as proved by beds of sea-shells ; and lake Champlain up to 300 to 400 feet, the lake having then been frequented by whales and seals ; and part of the coast of Maine of over 200 feet ; but New Haven, according to the above-mentioned record, only 25 feet.

26. To Light House Point and South End—A Walk or Drive.

The Old Light House is three-fourths of a mile southwest of the southern extremity of Morris Cove beach, and South End nearly a mile south of the same point. They are reached by different roads, and no sea-border road connects them for want of a bridge across a creek.

Leaving the south angle of Morris Cove, the road to the Light House passes over outcrops of a whitish granite or granite-like gneiss; and this is the rock of the coast region. It is usually rusted, and hence it is almost impossible to obtain an unaltered specimen. The reason why may be ascertained by examining a fragment; for it will be found that the scales of black mica are the center from which most of the rust proceeds. The mica contains iron, and hence the rusting. It is a destructive process to the rock, for it ultimately takes out the mica, so that the other grains, those of feldspar and quartz, fall apart. Or if the change goes on along fractures or rifts, it divides the rocks into blocks, which become, by the continuance of the change, rounded stones or bowlders. Thus granite and gneiss—often thought of as the most enduring of rocks—may go to easy decay if so porous that it absorbs much water.

The coast by the Light House and beyond is interesting to many for the sea-relics thrown up by the waves, and for the seaweed views along the shores at low tide.

The rocks to a height near high-tide level are almost everywhere covered with a layer of barnacles, in which myriads are crowded together; and wherever the water bathes them each at top is throwing out-and-in a cluster of slender jointed legs that serve as a net for gathering any food that comes within reach. Barnacles, as their *jointed* legs show, are crustaceans, and not mollusks. Along with the seaweeds and barnacles are also large clusters of *mussels*, brownish-black, oblong shells, two inches or so in length, attached to the rocks by long threads called the *byssus;* one species is smooth exteriorly (*Mytilus edulis*): the other, radiately furrowed (*Modiola plicatula*). Some of these mussels have a coating of barnacles.

On taking from the water a tuft of the more delicate seaweed, or from the tide-washed rocks, a group of mussels or barnacles, and putting it into a glass of sea-water, small animals of different kinds that were there sheltered, will be found swimming at large—including several crustaceans, of different genera, one or two species of mollusks, and perhaps some minute sea-worms or annelids. By drawing a small cambric net through the water among the seaweeds, then turning it inside out and rinsing the lower corner in a glass of sea-water, many other species will be added to the collection before made. The seaweed thrown up on the beach conceals multitudes of small crustaceans, which, if it be turned over, will hop away for concealment again. These *sand-fleas*, as they are called,—but undeservedly so—belong to the genus *Orchestia*, one of the genera of 14-footed or "Tetredecapod" crustaceans. They may often be seen hopping over the beach far away from any seaweed. After a storm, large semi-transparent, jelly-like masses are frequently found on the beach, which, if restored to the water, will show, by their radiate character, that they are *jelly fishes*, or *Medusæ* (Acalephs), and exhibit, if uninjured, much beauty of form and delicacy of structure. Occasionally also *Actiniæ* or *sea-anemones* are thrown ashore, of kinds living below low water mark; and besides these, mollusks and fragments of coral that at other times are rare. In the marsh, along the borders of the stream that enters the Sound just to the east of the point, there are numerous holes that are the lurking places of the *soldier-crab* or *fiddler* (*Gelasimus palustris*), a species broader than long, of which the males go about with one large-handed arm held directly in front, and looking as if, bully-like, always ready for a fight. They are often outside in large numbers, but at an approaching tread, at once run to their holes.

Most of those who visit the shore pick up its shells or gather its seaweeds, and many have a wider interest in the products of the sea. We therefore mention the names of the more common kinds that may be gathered here, and at other points on the coast, and give such descriptions as will enable even the unscientific to identify them.

Algæ or Sea-weeds.—These plants grow on rocks, or the sands, from high-water mark down to a great depth, and some-

times float in the water. There are three grand divisions, based on their colors ; the *green*, the *red*, and the *olive-colored* or *black* Algæ. A few of the species commonest on this coast are :

Fucus vesiculosus and *F. nodosus*, or *Rock Weeds.*--Very abundant on rocks between tide-mark, forming great bunches of dark olive or blackish-green flattened branches, which commonly bear many oval or roundish air-bladders. *F. nodosus* has longer and smoother branches than the other species.

Laminaria saccharina, the *Oar-weed* or *Devil's-apron.*—An olive-colored ribbon, 4 to 10 feet long and as many inches wide, having a leathery consistence, tapering at the lower end into a cord-like stem several inches long. Occurs on rocks below low-water mark, and is often cast up on the shore by storms.

Ulva latissima or *Sea-Lettuce.*—Found floating, or growing from stones, and looks like torn pieces of pea-green and grass-green silk. This is the sea-weed most useful in marine aquaria. It is sometimes called also *Sea-Cabbage.* A sea-weed of like structure, and color, but growing in very narrow ribbons, on stones, is of the genus *Enteromorpha.* It is also useful in aquaria.

The commonest red Algæ are :

Chondrus crispus.—This is the true *Carrageen* or *Irish Moss.* It is plentiful near low-water mark on rocks, forming dense tufts of flattened branches only $\frac{1}{8}$ to $\frac{1}{2}$ of an inch wide, which, forking repeatedly, become very numerous and crowded ; color dull red or greenish-red, and when bleached nearly white. In collecting it to make jelly for the sick, it must be washed many times in fresh water to clear it of small crustaceans, and then dried in the sun.

Dasya elegans.—More delicate than any feather, with countless branches, the whole of the richest crimson. It is often found after a storm, floating near the shore. There are also other red species of the genera *Grinnellia*, *Callithamnion*, *Ceramium*, etc. On account of their graceful forms and red color, they are often mounted on cards or heavy paper, and admired under the name of "sea-mosses" or "flowers of the sea."

Dr. Harvey's work, published by the Smithsonian Institution, gives a full account of North American Sea-weeds, while those of New England and the adjacent coast are fully described in

Professor Farlow's work published by the U. S. Fish Commission in 1881. Moreover, we have among us an excellent source of information on the subject in Professor Eaton.

Among the animal life :

I. Sponges.—A bright scarlet sponge (*Microciona prolifera*), an inch or two high, sparingly branched, is rather common in the pools ; and as it is the only scarlet species in the waters, it strikes the eye at once. Another large massive kind has a yellow color, and is the *Cliona sulphurea.*

II. Actiniæ and Corals.—Two species of Actinia, or Sea-anemone, may be often found attached to the under surface of loose stones lying on the coast near low tide level. When taken up, it will contract and look like a mere rounded lump of fleshy matter ; but if the stone with the Actinia attached is put into a vessel of water and left quiet, it will expand and show its flower-like form, presenting a circle of slender arms or tentacles, with a mouth at the center. The common brown one is *Metridium marginatum ;* the more slender, delicate flesh-colored one, having long white tentacles, is *Sagartia leucolina.*

Astrangia Danæ.—A coral, occasionally found in pieces an inch or two across, on the rocks or beach, where it has been thrown up by the sea. It is white, and has shallow radiated circular cells over its surface, a fifth to a sixth of an inch in diameter. It is sometimes dredged up alive off the coast, and is then a beautiful object when its polyps are expanded. It has all the characters of the ordinary coral of coral reef seas.*

III. Mollusks. 1. Bryozoans.—The leathery sea-weeds and the shells are sometimes covered here and there with very thin whitish crusts, which, under a lens, may be seen to consist of minute cabin-like cells. In a tumbler of salt water, the surface will soon produce a crop of delicate flowers, a circle of slender arms having expanded from each cell. The mouth of the animal is in the center of the flower. These Bryozoans are the smallest and lowest of Mollusks. They look externally like polyps, but

* For a figure of the animal see "Sea-side Studies," by Mrs. Agassiz and Alexander Agassiz ; also, Dana's "Corals and Coral Islands," page 68. Another very convenient sea-shore companion, containing figures of all the common shells, crustaceans and other species of the coasts, is "Life on the Sea-shore," by J. H. Emerton.

internally are not radiate. Besides the species forming crusts, there are others that are delicately branched, the branches consisting of one or more series of cells. Some of the branched species containing cells are *Sertularians* of the division of Hydroid Medusæ, instead of Bryozoans. In the Bryozoans the cells are independent cavities while in the Sertularians they all connect with a tube which runs along the axis of the branch or stem.

2. LAMELLIBRANCHS (so-called from the lamellar form of the gills, also Bivalves). *Anomia glabra.*—These concave, semi-transparent shells, of yellow, orange, and sometimes salmon colors, an inch or more across—are the most common kind on the beach, and are often called *jingle-shells.* Within some of them a thin flat shell may be found, which is the under valve of this bivalve. The Anomia, when living, is always attached to stones, or to other shells, and especially to the oyster, and the attachment is made by means of a muscle which passes through a large hole in the under valve. Anomias, Crepidulas, sponges and bryozoans may often be found alive on the fresh oysters in an oyster shop, covering the outside of the shell ; and it is only necessary to put the oyster into a bowl of pure sea-water (such as may be obtained off the end of Long Wharf) to make them show out their characteristics.

Mytilus edulis and *Modiola plicatula*, or *Mussels.*—These are mentioned above.

Ostrea Virginiana.—The common oyster.

Pecten irradians.—The common *Scallop* of the coast. A nearly circular, shallow shell, 1 to 2 inches in diameter, with one side, that of the hinge, nearly straight, and the exterior surface radiately furrowed from a point near the center of the hinge-line. The shells are common on the beach. It occurs living over some of the outer flats and in shallow water.

Mercenaria (formerly *Venus*) *violacea.*—The common round clam. While the oyster is always a stationary animal, being fixed in the mud or to the rocks, the clam has locomotion, and in this and other ways shows its superiority in rank.

Argina (formerly *Arca*) *pexata.*—A shell, one to two inches across, shaped much like the common clam, but longer in propor-

tion, and having the outer surface radiately ribbed, covered when fresh with a black scaly coating, and the hinge surface furnished with a multitude of small teeth.

Scapharca (formerly *Arca*) *transversa*.—Like the preceding in its numerous small teeth along the hinge-surface, but more oblong, flatter, and having an abrupt angle between the side of the shell and the upper part behind the beak; this angle extends from the beak obliquely downward and backward.

Hemimactra (formerly *Mactra*) *solidissima*.—Resembles the round clam, but is a little more oblong, and has a triangular spoon-shaped cavity at the center of the hinge-surface. The larger shells are often four inches long, but great numbers on the beach are less than an inch; the latter are young shells.

Mulinia (formerly *Mactra*) *lateralis*.—This is a small shell, usually about half an inch long, which closely resembles the young of the preceding. It is more swollen, and each valve has a sharp ridge passing from the hinge to the outer edge near one end. It lives on the mud flats, just below low-water mark, in great abundance.

Mya arenaria.—The common long clam. The shell is nearly twice as long as broad, and when the valves are closed it gapes at either end. Those along the beach vary from half an inch to two and a half inches and more. It lives in sand-flats near low-tide level. The vertical holes often occurring in such flats, half an inch or less in diameter, usually lead down to a long clam; the tread of a person over the flat often occasions a spurt of water out of the hole, arising from the clam suddenly closing its shell and throwing out the sea-water from the cavity about the body, in which the gills or branchiæ are contained.

Ensitella (formerly *Solen*) *Americana*.—A long narrow curving shell, called from its shape *Razor Shell*. It is often five or six inches long. The length is about five times the breadth (or more properly height). The shell has a delicate shining epidermis; and when closed it gapes at either extremity like that of the Mya.

3. Gasteropods (Univalves). *Crepidula fornicata*.—A concave shell, somewhat boat-shaped, having a shelf in the smaller end, or like a boat with a seat behind. It is one of the most common shells of the beach. When living it is commonly attached

to the shell of the oyster, but occurs also on other shells, and even on stones. There are also two other less common species of Crepidula. One, the *C. unguiformis*, is distinguished by its white color ; it lives inside of the old shells of the Fulgur and Sycotypus. [See below.]

Neverita (formerly *Natica*) *duplicata.*—A spiral shell, with the spire only very slightly prominent, and no beak at the other extremity ; the form is nearly round, though not so high as broad. Adjoining the inner margin of the aperture the shell is abruptly thickened. Often over two inches in diameter.

Littorina palliata.—A small rather thin shell, light yellow to dark brown in color, with a short spire, nearly round aperture and no beak. It is an eighth to a third of an inch across. It is pretty sure to be caught in a cambric net. Another species, *L. littorea*, the European *periwinkle*, has recently become naturalized along our shore and is everywhere very abundant. It is similar in form but much larger, thicker and darker in color.

Fulgur (formerly *Pyrula*) *carica.*—A large spiral shell with a long beak and prominent spire, sometimes four inches across and six or more long, having a row of tubercles on the body of the shell and the whorls of the spire. Fragments of this shell and of the following are common on the beach, and after a storm living specimens may sometimes be obtained.

Sycotypus (formerly *Pyrula*) *canaliculatus.*—Like the preceding in size and general aspect, but the spire has a deep angular channel along the line of the ordinary suture between the whorls. There is often found on the shore a long membranous cord, bearing a series of membranous cells, about $\frac{3}{4}$ inch across, attached crowdedly to one side of it, but somewhat spirally. It is the spawn of this or the preceding species ; each of the cells contains a large number of eggs or young shells.

Urosalpinx (formerly *Fusus*) *cinerea.*—A whitish or yellowish-white shell, an inch or so long, with a prominent spire and beak. The whorls as well as the body of the shell are crossed vertically by prominent ridges and also spirally with fine ridges. Common in the pools and shallow waters. It is popularly called the *drill* or *borer*, as it is the shell which bores holes into oysters to suck out the juices ; it has for this purpose a mouth, armed well with minute teeth, which may be elongated into a kind of proboscis.

Ilyanassa obsoleta.—The small black shell that may be seen everywhere over the flats when the tide is out. It has a rather prominent spire, quite a short beak, and the aperture within is shining black. The outer surface is marked spirally with very faint ridges, which become rows of points on the spire. Length, two-thirds of an inch. The flats after they have been bare for an hour are usually crossed in all directions by their tracks.

Tritia (formerly *Nassa*) *trivittata.*—Resembles the preceding, but is a more slender shell, is nearly white, and has the surface finely chequered owing to the crossing of delicate vertical and concentric spiral lines or ridges. Occurs along the beaches.

III. Articulates.—The water Articulates are mostly either crustaceans or worms.

Crustaceans. *Libinia canaliculata.*—A large crab, triangular or obtusely pointed in front, with rather long legs. Common along the rocky shores at the Light House, and alluded to above. Some specimens have the body 4 or 5 inches long, and the spread of the legs 15 inches.

Cancer irroratus.—Much broader than long, with the front semicircular, and nine slightly prominent, broad teeth on either margin outside of the tooth that adjoins the eye. Breadth 2 to 4 inches. The back shell, or *carapax*, is often found on the beaches.

Platyonychus ocellatus.—About as large as the last, but nearly as long as broad, with a semicircular front, and five very prominent and somewhat distinct sharp teeth on the margin outside of the eyes, and three between the eyes. A beautiful species, spotted with small rings of purple. It is often called *lady-crab.* The carapax is not unfrequent among the shells of the beach. Lives in shallow water among the eel-grass.

Carcinus Mænas.—Like the preceding nearly in form; but the five teeth outside the eyes are less prominent and contiguous, and the front, which projects a little between the eyes, has no sharp teeth, and has at its center a slight notch instead of a tooth.

Panopeus Sayi and *P. depressus.*—These two species are called *mud crabs.* They are usually about an inch across and both have the large claws black. The last-named has the back most flattened. Both are very common under stones on muddy shores and among oysters.

Gelasimus palustris. — The soldier-crab, mentioned above. There is also a second species, *G. pugilator*, found along the beach, just below Tomlinson's bridge.

Eupagurus longicarpus.—The hermit-crab. A much larger species, *E. pollicaris*, lives in the shells of the Fulgur and Sycotypus.

The Lobster (*Homarus Americanus*), and the crab of the market (*Callinectes* (or Lupa) *hastatus*), are not often found on the Light House beach. They sometimes are caught in moderately deep water in the harbor, but come mostly from the coasts outside. The hind legs of the crab are swimming legs, and for this purpose the last joint is broad, elliptical and thin.

Squilla empusa.—A very singular, elongated crustacean, with remarkable comb-like claws, is occasionally thrown on the beach at South End. It lives in burrows, below low-tide level and grows to the length of six or eight inches.

The above (with all crabs, shrimps, or the like) are ten-footed or "Decapod" crustaceans. To another group or order, that of the 14-footed or "Tetradecapod" crustaceans belongs, as has been stated, the *Sand-flea* or *Orchestia* of the beach. Its remarkable feats at leaping are accomplished by means of its tail, or rather the abdomen or hinder portion of the body. Among the small crustaceans that may be collected with a cambric net, as explained, there are other related species, of the group of Gammarids, which swim with great rapidity, either by jerks by a shove of the tail, or more steadily by the use of swimming legs projecting from the under surface of the abdomen.

In another higher group of the 14-footed species (called from the nearly equal feet *Isopods*) the abdomen is much shorter, and locomotion is performed in the more legitimate way by the use of legs; and specimens of these also will probably be found in the bottle or glass of water which contains the rinsings of the net. While the former are swimming species, the latter are crawling. The former may sometimes be found scrambling over the bottom of the glass, but will soon give a jerk and be off swimming.

Entomostracans.—A tumbler of sea-water from the pools at low tide, especially if taken up from among the sea-weeds, is sure to contain some minute species of this lowest order of Crustaceans. Some are of the *Cyclops* tribe, as certain one-eyed infinitesimals (a line or less long,) are called (actually two-eyed, but the two

are on a single spot of pigment, and look like one); and others, even more minute, have bivalve shells like a clam, and are of the tribe called *Ostracoids*, from the Greek for *shell*, and whence comes also the more familiar word *oyster*. They often lie on the bottom of a tumbler as if without life. But soon, antennæ are run out in front, and legs appear along one edge or side, and off they swim in lively style.

Barnacles have been mentioned above. They are among the lowest of Crustaceans, being so low as to live a stationary life, like plants. In the young state, when half a line or so long, they swim at large for a while, and look like Ostracoids. But after a few days, they light on the rocks or sea-weeds, by means of a pair of arm-like antennæ proceeding from the head, and in that act lose their freedom. They soon grow beyond the size which their diminutive life-systems could wield or give locomotion to, secrete a box-like stony envelop around the sides of the body, and two moveable valves at the top to close or open it at will; and, thus boxed in, they are at almost incessant work, if the water covers them, throwing in and out a net-like group of legs to catch their prey. Whenever the tide recedes and leaves them bare on the rocks, the valves close tight, and water enough is thereby confined to keep them in good condition.

Limuloids. The Horse Shoe (*Limulus occidentalis*) differs from Crustaceans in many respects, and is the nearest of living species to the ancient Trilobites. It is often met with on the beach in dead specimens, both young and old, and may be fished up alive from shallow depths. They are often 15 inches broad, and, the long spine-like tail included, twice this in length. The form of the front part of the shell beneath is a little like the hoof of a horse, and hence the popular name. The first or basal joints of the legs play the part of jaws, and they are the only jaws that the mouth is furnished with; in other words, the jaws in this degraded species are, through enlargement and elongation, made into good legs. They are well provided with the means of sight. The shell has above one front spine, and posterior to this a transverse row of three spines; either side of the front spine there is a *single eye*; and on the outside of the corner of the three spines, a large convex *compound eye*, combining, as may be seen under a lens, a large number of eyes, each of the minute spots in the compound eye having a separate crystalline lens.

27. To Mansfield's Grove in East Haven, and Short Beach and Double Beach in Branford.

East Haven is reached by following the road eastward from Tomlinson's bridge, or by turning into this road if the Chapel Street route is taken. At East Haven go southward by the east side of the public square. After the turn eastward pass two roads coming in from the south ; then take the third in order to go to Mansfield's Grove, a beautiful spot ; or continue eastward to the bridge across Farm River. The roads over this southeastern part of East Haven go partly through thin or half grown woods.

Farm River, in this its lower part, is really a small fiord ; it has banks of granite-like gneiss, and seaweeds, barnacles and mussels are growing on the rocks, as at the old Light House. It is sometimes called Stony River.

From the bridge it is hardly a fourth of a mile south to Short Beach, and about a mile east and then half a mile south to Double Beach.

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28. Around Saltonstall Lake from East Haven to Foxon and Fair Haven—A Drive or Long Walk.

Saltonstall Lake, the scene of college boat races, was called in colonial times the Great Pond, and Furnace Pond, although one of Nature's smaller lakes. Its present name commemorates the residence on its borders for awhile after 1709, of Gurdon Saltonstall, governor of Connecticut from 1708 to 1724, who was instrumental in procuring the removal of Yale College from Saybrook to New Haven. His portrait hangs in Alumni Hall, and a sketch of his life, by Prof. J. L. Kingsley, may be found in the New Englander, vol. ii, 1844.

Saltonstall Lake is three miles long and 400 to 500 yards wide (Plate I); and although so narrow has a depth at one place (according to the Bache map) of 107 feet. Lying by the east foot of the long bow-shaped Saltonstall Ridge, it owes much of its beauty to this high forest-covered border. From East Haven village, a fine view of it may be obtained by taking the road

northward to a point on Saltonstall Ridge just beyond the railroad—the distance half a mile.

In the drive around the lake to Foxon the chief feature in the scenery is the ridge instead of the lake. Going through East Haven eastward the little stream is crossed by which the Lake discharges into Farm River, and in this discharge it passes over a low part of the trap-dike. "Iron works" were here established by the first generation of colonists, "bog-ore" from North Haven and elsewhere having been brought to supply the furnace. Hence came the name of "Furnace Pond." The works were discontinued in 1679–80, and a grist-mill soon after established on the site.

Having passed the south end of the lake, take the first road northward. It passes near and in some places over a low interrupted dike or trap, the lake lying really between two nearly parallel trap-dikes. After two miles along it, a road comes in from the east. At this place, there is by the roadside, a ledge of coarse sandstone in which are a few stones of trap, proving, like other cases in the vicinity, that some of the sandstone of the region was made after the eruptions of trap had commenced.

The road continues northward for half a mile, then goes eastward, and then northward again, and, soon after the last turn, commences an ascent to the summit of Saltonstall Ridge. A shallow pond to the west is overlooked before reaching the trap of the ridge. On commencing the descent northward, take the first road west and follow it in its bend northward across Farm River to the small village of Foxon. From Foxon the road is nearly straight to the north-and-south Fair Haven road, about 1¾ miles distant; and from the junction with this road it is nearly a mile to the Fair Haven bridge over the Quinnipiac.

The deep trench of Saltonstall Lake, with a high trap ridge on the west, and another parallel line of trap near the eastern border, looks as if it had once been the course of a river. But the outlet in East Haven is over rocks above tide-level; and that of Farm River nearer the coast has a rocky bottom at shallow depth; and hence if the land were elevated, the water in the Lake would not run out, so that river action could not have made it. The old glacier might have ploughed out the sandstone to the required depth; and this is probably the true explanation.

29. To Branford and some strange hills of Bowlder Conglomerate—A Walk or Drive.

Through the village of Branford passes the boundary line between the Jura-Trias Sandstone formation and the gneiss of the region south and east. Near the boundary on the limits of the village, and partly within the gneiss, occur the easternmost of the trap-dikes. These dikes have several points of great interest, briefly mentioned on page 33. About $1\frac{1}{2}$ miles northeast of these dikes there are several low hills which consist of rounded stones of trap, sandstone, gneiss and other rocks, some of these stones 2 to 3 feet in diameter. The accumulation looks much like bowlder deposits of the Glacial period. The dikes and the hills of bowlder conglomerate are described in the paper by Mr. Hovey, referred to on page 33; and in it the reader will find a full account of them and a map showing their location. The hills of conglomerate are of unascertained origin; and, since they have great interest, one way to reach them is here stated. In the preceding excursion a small pond is alluded to as seen west of the road just before crossing Saltonstall Ridge. By taking the road that goes eastward a little north of this place, and continuing eastward for $2\frac{1}{4}$ miles (passing on the way one southward road), and then turning southward, after going three-quarters of a mile the first house on the road will be reached. One of the hills will be found to the west, by passing through the barn-yard north of the house and continuing on for a dozen rods or so. The hills are covered with forest trees and should be ascended to the crest of rock at the summit. Such agglomerations of large stones of trap, sandstone and gneiss cannot be volcanic ejections. No stream of water could have transported and deposited them unless it were a great torrent descending a steep valley; and the aid of ice also would seem to be necessary. Gneiss exists to the eastward and northeastward, and so also trap and sandstone; but there are no steep westward slopes there descending from icy heights, and no known record of any in earlier time besides the facts here presented.

30. To the East Haven Sandstone Quarries—A Walk or Drive.

Out Chapel Street to the Ferry Street bridge in Fair Haven. From the bridge, the top of a derrick may be seen over the high hill to the eastward. For the walk from the bridge the course is directly east, across the railroad and up the hill. For the drive, go down Meadow Street to Center and then a short distance northward on Prospect street.

But before going farther, the rocky point west of the river below the bridge deserves consideration. This spot was the "Ferry Point" or "Red Rock" of early colonial times. The name "Old Ferry Point," which is still sometimes given to "Red Rock," commemorates the site and the mode of crossing to East Haven prior to 1790, when the more northern of the two Fair Haven bridges was built. The first road out from New Haven followed the present course of State Street, crossed "Neck Bridge," (that of State Street over Mill River) then turned to the right and went diagonally across "the Neck" to the ferry; and on the East Haven side, it continued toward the iron-works at the lower end of Lake Saltonstall or "Furnace Pond." The selection, in 1638, of the center of the New Haven plain for the site of the future city tended to draw off the population from the banks of the Quinnipiac. But the harbor privileges of the latter place have always given it importance; and now, through its oyster trade, sandstone quarries and shipbuilding, the settlement has become the largest of the villages about the bay. Further, the red sandstone at this place is a good example of the ordinary characters of the rock; its eastward dip, and its variation in texture, some layers being a conglomerate, and isolated stones in it a foot or more in diameter. It exhibits also a case of bleaching to white the red color of the rock. The whitish streak seen along the top of a layer owes its color to the waters that soaked down from the soil above and flowed along the surface of the layer because the layer was a little clayey. Such waters carry along a little organic matter from the soil and this has the property of taking oxygen from the red iron oxide (Fe_2O_3) which is the coloring matter, (reducing Fe_2O_3 to FeO), and supplies also an organic acid or carbonic acid for combination with the iron (FeO); and

so the red oxide loses its color. Isolated spots of a similar color are common in the red rock, which some fragment of fossil wood may in a similar way have produced.

The top of the hill on the way to the derrick affords a fine prospect westward and northward. It includes the wide region from Mt. Carmel to the Sound ; and near the middle of it stands East Rock like an island in the great plain. As one of its striking features, Sachem's Ridge is projected against Pine Rock, covering all but its top, and the larger mansions of the ridge look like palaces built about its heights.

At the quarry, across the road, the general features of the sandstone formation are well displayed. (1) The granitic origin of its constituents,—only mica (of the three, quartz, feldspar and mica) being rare ; and the reddish feldspar grains generally showing good cleavage and luster instead of being decomposed. (2) The eastward dip of the beds of 15° to 25°, showing, like all the rest of the outcrops of sandstone in the Connecticut valley, that the beds had been shoved up out of their original horizontal position. (3) The existence of nearly vertical divisional planes or joints, from top to bottom of the quarry—a great convenience to the quarryman. Further, on the west margin of the quarry, there are large surfaces covered with glacial scratches, having the direction N. 15° to 18° E. For a long time after the quarry was first opened there was a rounded "ogee" of sandstone, 20 to 30 feet wide, and 300 feet long, which had been shaped by the ploughing action of the glacier. Every new removal of the soil opens to view other scratched, planed or ploughed surfaces.

Going eastward from this quarry over the hills 500 yards, another quarry is reached. It opens out on the road next east, and the place is therefore accessible to a carriage. The same features are here exhibited as at the first quarry, that is the same granitic sandstone, the same eastward dip, and extensive joints. The surfaces of the joints, large and small, are usually smoothed and grooved *through mutual friction*, and are good examples of the "slickensides" of miners. Besides this, these smoothed scratched surfaces have generally a white coating, which was derived, it is believed, from the grinding of the feldspar of the sandstone into a paste and its subsequent hardening. At this quarry the upper surfaces of the sandstone layers also are slicken-

sided for hundreds of square feet, showing that there was movement of layer over layer as well as slipping along multitudes of fractures, when the position of the sandstone was changed from horizontal to a dip eastward of 15° to 25°.

A very narrow trap-dike intersects the sandstone of the quarry, the rock of which is much decomposed and broken into small fragments. Extensive glacial scratches have also been visible at this quarry. The above are common features through all the quarries of the region.

The return may be made by following the road northward and then turning eastward to Fair Haven ; or by taking the road just south across the railroad, and then going first east and then south to Forbes Avenue and Tomlinson's bridge.

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31. Sandstone Ledges and Trap-dikes along the Shore Line Railroad Track to Saltonstall Lake—A Walk.

The part of the Shore Line railroad here in view may be reached by going out Chapel Street, crossing the Ferry Street bridge in Fair Haven, and continuing on to the crossing of Meadow and Center Streets. Between this point and Saltonstall Lake the railroad cuts through seven hills or ledges of rock, and it is a good opportunity for the examination of the sandstone and its intersecting trap-dikes.

The *first* ledge consists wholly of sandstone. This sandstone, it will be noted, is much fractured, and all the pieces have their surfaces covered with scratches or slickensides, showing how general was the slipping of parts attending the upturning of the sandstone.

The *second* ledge has a trap-dike 22 feet wide cutting through hard sandstone. In the *third*, a trap-dike 17½ feet or 18 feet wide occupies almost the whole of the ledge, there being but little sandstone at each end, and that much obscured by the baking it has undergone. The trap is very much cracked and decomposed. The *fourth* ledge is the largest of the series, and consists only of sandstone in thick layers. The *fifth* ledge lies wholly south of the road, its northern end only having been cut off. It is one of

the larger trap-dikes of the region. In the field on the opposite side of the railroad there is another hill of trap, and farther to the northeast still another higher ridge. Between the latter and the railroad there is a low hill of brick-red sandstone. The road next passes over a long range of East Haven meadows little above sea-level.

The *sixth* ledge is low and long, and consists of sandstone ; but in its eastern part, where the sandstone is not well exposed to view, there are loose blocks of trap on either side of the road.

A short distance to the eastward, the carriage road—but not the railroad—cuts across the south end of a trap-ridge which extends far north parallel to the Saltonstall Ridge ; it is separated from the latter only by the valley of Farm River. The section of the trap and sandstone along the road is the very interesting one represented in its eastern part by the figure, page 32, in which the trap rests on upturned ledges of sandstone, proving that the upturning had taken place before the eruption of the trap. In the western part of this cut the trap looks as if it came down to the level of the road ; but whether this is so from undermining, or whether it is the original position, it is not easy to say.

The trap of this Farm River ridge, like that of Saltonstall ridge, is more or less *amygdaloidal*—that is, it contains small nodules of some white crystalline mineral distributed through the mass. The mineral is mainly calcite (carbonate of lime), and occasionally quartz. These nodules are often nearly cylindrical, and two or three inches long. Many of the loose, half-decomposed masses of rock are full of holes arising from the removal of the calcite. When the trap came up in the melted state its outer portion became filled here and there with cavities through the expansion of steam or of vapor of some kind. These cavities subsequently became occupied with the calcite and quartz. This is the usual mode of origin of an amygdaloid—the name, derived from the Latin for almond, alluding to the *almond*-like form presented sometimes by the nodules, and having no reference to their mineral nature.

The ovoidal holes were undoubtedly made by vapor of water, or steam, like those of cellular lava ; but the cylindrical were probably a result of the explosive vaporization of liquid carbonic acid, as stated on page 33. The trap of the Saltonstall

Ridge—the *seventh* in the series—is amygdaloidal to the east ward alongside of the railroad and at other points on the borders of the lake.

The trap of Farm River and Saltonstall ridges, and of nearly all of those of East Haven, and of many to the north, has little luster and decomposes easily to a yellowish brown earth, quite unlike that of East and West Rocks; and it is so much broken up that the glacier had no chance to get a large bowlder from them. When examined in thin slices microscopically, instead of exhibiting the constituent minerals in a transparent condition, like the trap of West Rock, they are found to be clouded or opaque, and there is much green chlorite and little unchanged pyroxene. This alteration of the trap was produced by means of water or steam—for the chlorite formed is a hydrous mineral, and so are some of the other products. The water gained access to the trap of these dikes while the melted rock was on its way to the surface. The melted trap came up from great depths, through fissures intersecting first crystalline rocks, and then, with few exceptions, through sandstone. The "great depths" did not supply the moisture; for if so, all the trap of the New Haven region should have been essentially alike in amount of water. The crystalline rocks did not give it, for the trap of the dikes intersecting only the crystalline rocks contains no more water than that of West Rock. It must therefore have been taken in from supplies of water at the bottom of the sandstone or at levels within it between its loosely packed beds.

Besides water, the trap while on its way up received some carbonic acid. This it may have taken from limestone adjoining some part of the walls of the fissure. It also gathered in mineral oil or petroleum from carbonaceous shale; for inspissated bitumen occurs in amygdules elsewhere. The calcite making amygdules was made from lime afforded by the labradorite or pyroxene, constituents of the trap; it combined with the free carbonic acid and so made the calcite. The quartz or agate in other amygdules came from the silica set free in the alterations undergone by the constituents of the trap; for chlorite, the most common product, uses only two-thirds of the silica of pyroxene.

Saltonstall Ridge may easily be ascended from the railroad for a ramble through the woods, and the enjoyment of views along

the lake; but there are no columnar precipices to be visited, and, owing to the forests, no points for good distant prospects. The distance along it to Foxon is 3 miles; from Foxon to Fair Haven $2\frac{3}{4}$ miles.

32. To Rabbit or Peter's Rock—A Walk or Drive.

The way to Rabbit Rock is by State Street, across Mill River, and then, after passing the railroad track, across the Quinnipiac and the Quinnipiac meadows. Beyond the meadows eastward the road makes an intersection, like a narrow letter x, with the East Haven road from Fair Haven. Continue on beyond this intersection, crossing a little brook, and soon after enter to the right, where a road and path lead to the summit of the Rock. The distance from New Haven is about $4\frac{1}{2}$ miles At Rabbit Rock there is the most remarkable display of columns of trap about New Haven. The columns are three or four feet in diameter, and some of them are very nearly regular hexagons. They form a bold front to the west, and make a polygonal pavement over part of the summit.

The Rock may be reached also from Fair Haven, from which it is three miles distant.

The view from the Rock is literally panoramic, taking in the whole horizon. It includes the Sound far to the southeast, near Branford; the whole range of the Quinnipiac meadows; Mt. Carmel and the Hanging Hills of Meriden on the north; the isolated East Rock group of heights, in the great plain; the West Rock Ridge; the Woodbridge range to the south; with numerous spires, and various clusteıs of houses in all directions, besides the wide-spreading city of New Haven.

33. Up the Quinnipiac to North Haven and its Brick-yards—A Walk or Drive.

Crossing Whitney Lake above Whitneyville it is only a short walk or drive to the Quinnipiac Valley. The brickyards commence south of the railroad station of Quinnipiac, and occur at intervals from there to North Haven, on the east side of the

meadows, and also to a less extent on the west side. The general characteristics of the clay may be well studied at the clay pits of Captain Crafts, at the Quinnipiac station: its thinly laminated structure, with each little layer one-third to half an inch thick, consisting of a bottom portion of fine sand and sandy clay, and the rest of the fatty clay. Besides clay, the deposit has turned out an occasional glacier-scratched bowlder, and one from a depth of 6 feet that is 4 feet in diameter. In addition, two leg bones of Reindeers have been found at Captain Craft's pit, which are described by Prof. Marsh as a shoulder-bone (humerus) and a bone of the right leg (tibia), of the true Arctic Reindeer (*Rangifer tarandus*), not of the Canadian Caribou. Moreover they belonged to two different individuals.

There are also concretions of flattened or lenticular form. They are often called clay-stones, but are really calcareous. Such concretions were probably made from land or freshwater shells, which in a ground-up state were deposited with the clay. Through the dissolving power of percolating waters, the material of the ground shells passed into solution, and the concreting action went forward. The concretions are widest horizontally, or in the direction of the layers of the clay, because water percolates easily in this direction and with comparative difficulty through the layers vertically.

The clay-pits in the vicinity of North Haven afford similar facts, except that no Reindeer bones have yet been reported from them.

The geological history of this Quinnipiac region is interesting.

This broad tidal region of the Quinnipiac meadows, lying now at sea-level up to North Haven, but deep below the sea-level in peat and mud, and hemmed in on the south across from Snake Rock to the Fair Haven hills by the sand and gravel deposits of the New Haven plain, excepting a narrow channel for the river, must have been, at the time of the deposition of the clays, a great bay with a shallow outlet, in which the river waters, in times of moderate floods, brought sediment from the region just north, and dropped first the sand, and then, during the lake-like quiet which followed, the finer clay. It need not have been a lake, for a basin or bay with shallow outlet would have afforded the required conditions.

But the scratched bowlders dropped from floating ice to the bottom, while deposition was in slow progress, show that the time of deposition was close on to the Glacial period; probably soon after that submergence of Southern Connecticut of 25 feet, referred to on page 88, but before the flood from the melting glacier began. The ice was still over the region or on its borders, and Reindeers found an arctic climate and all else to suit their tastes. The New Haven plain had not been made, for the glacier was yet to melt and discharge its freight of sand and gravel.

Moreover, the Quinnipiac was then a small stream compared with Mill River (p. 57), and long continued to be small and feeble. Mill River, in contrast, was all the time a dashing torrent, the slope of its bed from Mt. Carmel down 10 feet a mile.

The glacial flood, when fairly under way, affected both streams, but in ways very unlike. It is a remarkable fact that the difference in the force and work of the two streams is registered in the deposits of the New Haven plain south of Snake Rock; and 20 years since, the evidence was visible in the cut made through it for the New Haven & Hartford railroad; and it would now be visible were it not for the slides of sand over the face of the cut. Up to a height of 25 feet, or the level of the submergence above referred to, the sands there deposited were those of the Quinnipiac. Mill River also worked in its own channel; each was independent of the other. But on reaching this level below East Rock, Mill River manifested its superior volume and power by the throw of its waters, sand and gravel across the broad Quinnipiac valley; and from this time on, as the flood augmented in violence, it controlled all Quinnipiac deposition, until the Fair Haven part of the New Haven plain was finished off at its level of 40 to 45 feet above mean tide. And at the same time it carried on its work over the central part of the New Haven plain to the bay.*

The Quinnipiac River regained its superiority at the close of the melting. When the flood was at its height, the depositions of sand and gravel along the course of the great Mill River reached

* The evidence of the facts, here stated (which is based on the stratification of the beds and the quality of the material), is given in the paper on the Topographical Features of the New Haven Region, referred to in a foot-note to page 2, and also in the American Journal of Science for September, 1875, volume x, page 173.

nearly flood-level across the valley, leaving only a narrow channel for the stream. But as the flood declined these deposits became a barrier to the diminished stream; and when the ice disappeared, and the Tariffville ice-dam broke away, the waters of the Farmington River turned northward to their old route; the Quinnipiac regained its channel; and to Mill River was left for water supply only the small part of the valley south of Cheshire.

During the continuance of the Glacial flood, Mill River had a length of 75 miles, it commencing at a height above 2000 feet in the Berkshire hills, and its drainage area was 450 square miles; while the Quinnipiac had then a length of only 18 miles and a drainage area of 65 square miles. After the flood, the length of Mill River was reduced to 15 miles and its drainage area, to 50 miles; while the Quinnipiac became a stream 33 miles long and 120 square miles in drainage area.*

The bricks of the brick yards also are instructive. It is well to observe the stages in the manufacture; and to know that the clay becomes red in baking simply because the heat drives off the water combined with the iron in the clay, or, less frequently, the carbonic acid—thus reducing the iron to the red oxide (p.). When overheated in the baking, the brick become partially fused, lose their red color, and sometimes run down in coarse stalactites. This shows that the North Haven clay contains something besides pure clay and quartz sand; for these are infusible materials. Iron is present and this promotes fusibility. But the facts indicate the presence of some other ingredients. An analysis in 1889 by Mr. O. H. Drake of the Sheffield Scientific School of a half-fused brick from the southern yard obtained the following for the composition: Silica 65·89, alumina 18·98, iron sesquioxide 2·97, iron protoxide 1·32, manganese protoxide 0.22, lime 2·29, magnesia 2·56, potash 3·15, soda 2·96 = 100·32. The amount of potash in the brick corresponds to at least 20 per cent. of feldspar in the materials. Nothing is added to the clay for brick-making except about 20 per cent. of sand and anthracite dust; so that nearly all of the potash must be present in the clay. The soda probably came, it is said, from salt in the added sand, derived from the sea. Ordinary clay when pure is

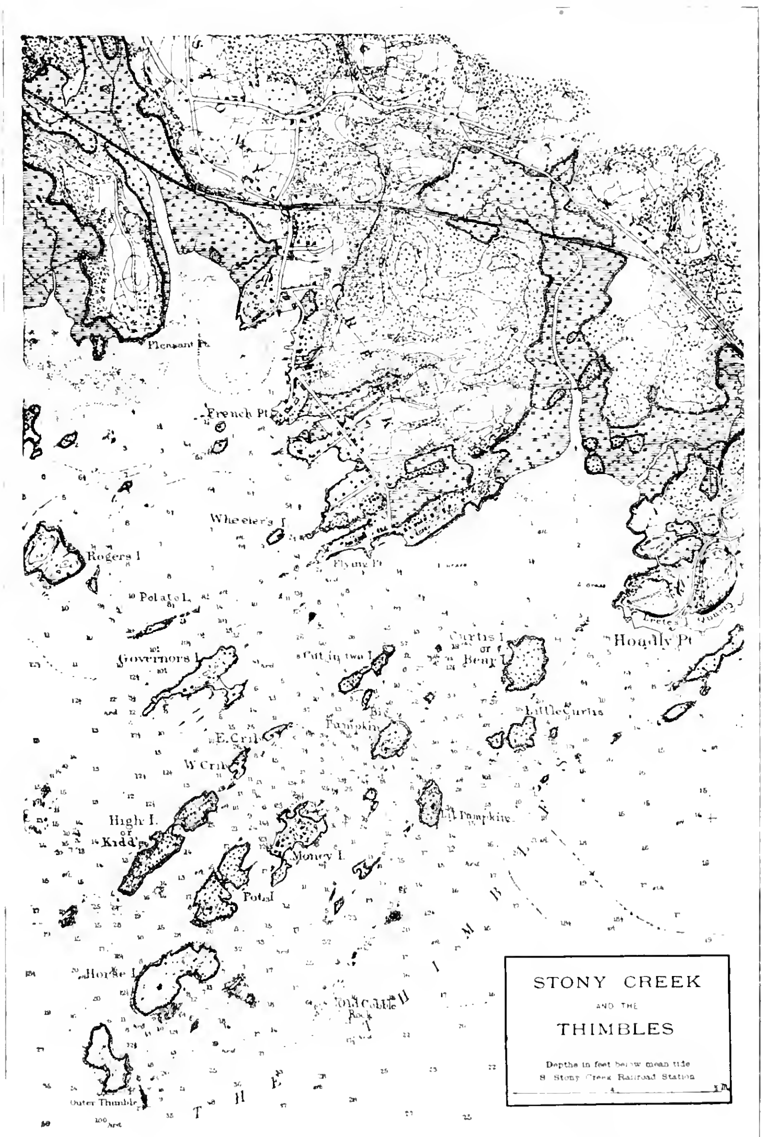
* On this subject see the American Journal of Science, vol. xxv, p. 440, 1883, and xxvii, p. 113, 1884.

derived from feldspar by the removal of *all* its 12 per cent. or more of alkali, and the introduction of water. Hence the North Haven clay must contain much undecomposed feldspar. The clay and ground feldspar of the clay-beds probably correspond in origin and fineness to the impalpable earth which causes the milky appearance of the waters flowing from beneath a modern glacier. The grinding of the stones in a glacier is a consequence of the change of position which goes on throughout it as it moves. The crystalline rocks from New Haven northward contain feldspar, and hence there was an abundant supply close at hand for the glacier.

34. To Stony Creek and the Thimbles.

Stony Creek is situated on the Sound to the east of New Haven, 11 miles distant by road, and half an hour by the Shore Line cars; and the "Thimbles" are small islands of light-colored gneiss and granite just off the shores. A steamer plies twice a day between New Haven and the islands.

On the map of the U. S. Coast and Geodetic Survey, of which a copy is here introduced, the archipelago contains nearly 100 islands, if all the bare rocks are counted; yet the largest is hardly three-fourths of a mile long. In a sail through the group new islands are seen in quick succession—all of them white rocks below, but the larger green above and mostly adorned with groups or groves of native trees. Even the bare rocks are often well shaded. Pines forty feet high and other trees as large rise out of crevices in the rocky pavement. Besides Pines (*Pinus rigida*), the groves or forests include Oaks (*Quercus alba*), a few sugar maples, Sassafras and Cedars; and among the shrubs are the Witch-hazel, Sumach, Juniper, Bayberry (*Myrica cerifera*). On several islands the summer residence of the proprietor, or a cluster of them, adds to the picturesque features of the scenery, although as yet no great amount of money has been expended in architecture. On Money Island and Pot Island there are hotels. Prof. Verrill is possessor of the "Outer Thimble," and has there a delightful summer home. The islands afford no long beaches to bring into line and heighten incoming waves, but, instead,


STONY CREEK
AND THE
THIMBLES
Depths in feet below mean tide
S Stony Creek Railroad Station
Pleasant Pt.
French Pt.
Wheeler's I.
Rogers I.
Potato I.
Governors I.
Cut in two I.
Curtis I. or Bear I.
Hoadly Pt.
Little Curtis
Big Pumpkin
E. Crib
W. Crib
High I. or Kidd's
Lt. Pumpkin
Money I.
Potal
Horse I.
Old Cobble Rock
Outer Thimble
Flying Pt.

bold fronts or slopes of square cut rocks, with also recesses, deep crevices, and long channels to receive and turn back the waters, quietly or thunderingly, according to the occasion; and at low tide many limpid pools and basins invite attention from their various sea-productions. The islands have also their great glacier-brought bowlders; their pot-holes of river origin, although they are sea-girt lands; shell heaps of the old Indian; and remarkable examples of rock degradation now in progress without aid from streams. The islands are among the many regions reputed to have been places of deposit for the buried treasures of Captain Kidd, and Money Island has been eagerly dug over in search of them.

On leaving the cars, first take a short walk along the railroad cut east of the Station. It affords some idea of the kinds of granite and gneiss which constitute the Thimbles. The rock is granite to the eastward, but at the western end a very micaceous gneiss is intercalated. Besides this, the surface north of the cut is one continuous glacier-record in grooves, broad channels, and smooth planings, telling of the abrading power of the glacier and the direction there of its movement—about S. 10° E. In view of the fact that such markings are found in all directions about New Haven, it may be inferred that the moving glacier did not slide over the gravel beneath it, but had the loose material in its icy grasp and made it work. This place was stripped of soil when the railroad was in construction about forty years since—the first train passing over the tracks to Saybrook July 1, 1852.

On the way to the boat-landing, an old granite quarry is passed on the west side of the road at *q*, but out of sight as it is over the hill. And here a bed of mica schist occurs to the south of the granite and appears to dip beneath the latter. The shores have other outcrops of gneiss with some of mica schist; and remarkable granite veins in these rocks with the red feldspar in large crystallizations are displayed along French Point, just beyond the boat wharf.

The route among the islands should include at least Money Island, remarkable for the results of degradation along its shores; Pot Island, which has Kidd's "punch-bowl"—a pot-hole—on its eastern shore, besides other examples of degradation; and Little Curtis Island, which is remarkable for its deep circular

pot-holes. Finally, in order to understand the variations in the granite and gneiss, the large Beattie, or Leete's Island, quarry, along Hoadly Point, should be included in the excursion. The finest granite is that of the Norcross & Redpath quarries, 1½ miles north of the R. R. Station.

The rock of the islands is mostly a feebly banded gneiss. Its planes of bedding or foliation—or those of the scales of black mica—are often in short zigzags, giving the rock much beauty. Here and there very micaceous beds intervene, but only locally. The dip of the beds is 20° to 40° westward.

A feature of the rocky basement of the islands observed from the boat in all directions is its nearly vertical fracture-planes or joints in parallel courses. The prevailing directions are N. 55°–60° W. and N. 30°–35° E. Many of the long joints are opened a foot, and some of the capes or points are divided by them into sections. High Island has a long vertical cliff, 25 feet high, which is due to a joint.

Landing on Money Island, the joints appear at every turn. Some of them are sufficiently opened to let the sea enter and ply its vocation of battering and loosening; and others, as already stated, have trees growing from them to carry on their destructive work of rending. In these two ways the coast of Money Island has become a succession of scenes of huge displaced blocks, and also of deep narrow water channels.

These displacements by the sea are often promoted by the micaceous layers in the gneiss, and the pieces of mica-schist occurring here and there which exist in the gneiss. A good example of the effect of much mica is seen close by the boat-landing on the west side of Pot Island, a little north of the steamboat wharf. The rock here has the usual westward dip. Only a few yards above the water, at a break in the rock, a very micaceous layer may be seen and traced downward, and the effects of its weakness observed. It is weak because water is absorbed easily along such layers; because the black mica oxidizes easily; and because the waves readily dislodge the scales of mica. On the east side of Money Island, east of the hotel, a micaceous layer intervenes between the more compact gneiss, with a similar display of its effects in hastening degradation.

Another kind of destruction observed on Money Island and elsewhere consists in the peeling off of thin plates from the exterior of the hard rock. The thin plates thus separated are sometimes several square feet in area and a fourth to three-fourths of an inch in thickness. This "desquamation" occurs without any appearance of decay in the rock. It is attributed to the expansion and contraction attending the changing temperatures of the day and night, or sunlight and shade; and it may be aided by the cooling dash of the waves of the returning tide after the heat of a day. Freezing of water in the crevices of the rocks must also have its rending or displacing effects, through the expansion attending the process; but probably only in the smaller crevices.

Decay of the gneiss through the oxidation of the iron in the mica, like that at the Light House (p. 89), is also illustrated to a marvelous extent. On Pot Island, over the lower area in front of the hotel, toward the western shore, several of the large blocks of gneiss have been broken across. Outside they looked like solid white granite, and the best of building stone. But inside they are rusted to a depth of a foot or more. The mica has disappeared; the feldspar and quartz are left rust-stained, but otherwise unaltered. The exterior of the deeply rusted masses derived its deceptive whiteness from a washing by the rains, aided perhaps by the presence in the waters of organic and carbonic acids. The bleaching extends to a depth of an inch.

This work of the rusting mica is well exhibited in the cut by the Stony Creek Railroad Station. Ten years ago, along the sides of the fissures in the granite the rust had become extended inward 6 or 8 inches, and an interior portion remained unchanged. Now through the whole length of the cut the surface of the granite is rusted. This rusting of the surface has been completed in 40 years. Fissures generally carry moisture at all times and hence the oxidizing process is rapid along them. But outside surfaces dry after being rained on, and hence the oxidation over them is slow. The weakness is due to the rock's being porous; so far as it takes in water, it rusts. Pyrite adds but little to the result.

The *veins* of granite in the region have considerable interest. They usually consist of red feldspar in large crystallizations with quartz and some mica, and rarely a little magnetite.

The gneiss of the islands has many such veins. At Beattie's quarry a large granite vein, near the middle of its western half, affords small pale green crystals of the mineral apatite (calcium phosphate). Apatite looks like beryl, but a touch with the point of a knife-blade will prove it to be too soft for that species. The crystals are small, seldom over a fourth of an inch thick. The best have been obtained from the debris about the vein; they had fallen out of the rock in the quarrying. The black mica (biotite) of the vein, which is in large crystals, decomposes so readily that the most of it will be found to have lost its lustre.

Veins are fillings of fissures from below or from either side by infiltration of solutions or vapors at a slow rate; very slow and prolonged to produce so coarse crystallizations of red feldspar as here occur. The rocks were variously shoved about as well as broken to make fissures for veins having the great irregularities observed on French Point.

Besides granite veins, quartz veins may be met with. They intersect those of granite when they occur together, and thus show that the latter were formed first. This order of succession in the veins accords with the fact that depositions of feldspar and mica form only at high temperatures, and those of quartz may be made at low, and therefore during the later stages of an epoch of metamorphic change and vein-making.

The pot-hole on Pot Island, called Kidd's Punchbowl, is on the rocky northeast shore, above the level of tides and waves. It is shaped like a bread-tray, being 2×4 feet broad and a foot and a half deep. It is hence a poor example of a pot-hole, and would hardly be called one were not its inner surface so well smoothed. The rocking of a large stone over the spot by the dash of the waves or the rush of a torrent may have made it. But if the work of the waves, or a torrent, the water-level was different from the present:—higher to give the waves a chance; but much lower to afford a land area for a river.

Little Curtis Island is well worth visiting for its two pot-holes on its eastern shore. These are deep cylindrical borings into the hard rock. The larger is $7\frac{1}{2}$ feet deep and 3 in diameter; and among the rounded stones taken out of it was one a foot in diameter. One of trap, is $16 \times 8 \times 8$ inches in its dimensions. The other pot-hole is 10 inches across and was originally, as traces of its upper part show, about 3 feet deep. It is situated

a little to the north of the other. Such vertical borings into a granite-like rock imply the long-continued revolution of a vertically-acting abrader. Waves cannot thus act. Neither could a cascade through the crevasse of a glacier, however well supplied with stones; for a glacier keeps moving, instead of stopping to make a vertical 7-foot bore into granite. Rapid streams along their rocky shores—making concentric whirls of stones owing to the form of the bottom and its position with reference to the current—are the only agency. Hence when the granite of Little Curtis Island was being bored, the present sea-bottom was above the sea-level. The map shows that the stream now flowing west of Hoadly Point was the probable agent. The time may have been the Glacial period. The above facts and others make it probable that during this period the land along southern Connecticut stood 100 to 150 feet above its present level.

Little Curtis Island has large Indian shell-heaps. The shells are mainly of oysters, and many are 10 inches long and narrow. There are a few of the round-clam, and none of the long-clam. Like others of the group, these shell-heaps have not yet afforded any arrow-heads or other implements, but they may to future searchers. The sea-border Indians, with food plenty in the waters, had little use for hunting apparatus. Moreover there is no evidence that the Indians cooked their oysters.

A walk through the extensive Beattie quarry is instructive. There are wide variations in the gneiss from the most strongly banded (in a cross-section), owing to the abundance of black mica in large scales, to the feebly banded; and the latter shades off into granite. The granite of the Stony Creek region contains usually two feldspars: a flesh-red, which is orthoclase or potash-feldspar, and a white, which is albite or soda-feldspar; and also two micas: the light-colored muscovite, containing little or no iron or magnesia, and the black biotite, containing both iron and magnesia. But mica of either kind is very sparingly present, and muscovite the least so. This gradation of gneiss into granite is attended therefore with a large diminution in the amount of mica.

The association of the two rocks and their frequent transitions show that they were formed under similar conditions. At the

same time, the large amount of iron and magnesia in one, and the very small in the other, is proof that the gneiss could not have been made from the granite, although a gneissoid structure may be produced in the latter by pressure. Further black mica schist (more or less hornblendic) alternates in some places with the gneiss and hence is a third kind of rock in the series—and a kind as much underivable in any way from granite as granite is underivable from a black mica-schist.

The rocks are examples of the metamorphic rocks of geology, that is, rocks that have been changed or metamorphosed from the condition of common uncrystalline strata into crystalline. The delicate wavy lines or zigzags in the planes of bedding or foliation in much of the gneiss of the islands is evidence that under the pressure to which the beds were subjected the rocks were more or less softened in some parts by the heat and vapor; and the fragments of mica-schist, from the size of the hand to those that are rods in length, found in the rocks, indicate that they were much broken, faulted and mended during the progress of the crystallization.

The decay of granite and gneiss in the region gives a hint as to the origin of the sands of the Red sandstone. The results of this decay are granitic sands, with only the black mica wanting, and the quartz and feldspar have very nearly the proportions in granite. Moreover they are colored or stained with iron oxide. These are precisely the materials needed to make the sandstone. The sands, therefore, were simply gathered from the land by streams and hurriedly transferred to the Connecticut valley estuary. Had the feldspar in the decay of the rocks been changed to clay (as is often done by the action of carbonic acid) there would have been clayey beds among the sand-beds; but these are absent from the New Haven region and are mostly so elsewhere. Had the waves of a seashore helped in their distribution, the feldspar would have been ground up and drifted off, and the sandstones would have been made mainly or wholly of quartz sands.

This explanation of the origin of the sandstone fails in only one point: the rock is colored with the red oxide of iron (Fe_2O_3), not with the brownish yellow oxide (Fe_2O_3 + water). To this it may be urged that the oxide produced in the region in Triassic

time by the oxidation may have been the red oxide, as it is now in some warm regions. If this was so, the explanation is complete. But if it is not admitted, there is the fact that the yellow oxide when heated to 212° F. in boiling water or otherwise, becomes the red, as it does in making brick. Consequently, heat coming up through fissures in the epoch of the trap eruptions and diffused through the waters of the Connecticut valley estuary, supposing the sandstone still submerged, might have made the rusty beds red. This result is not incredible in such a region, at a time when it was having eruptions of melted rock through enormous fissures along its whole length, and when heat and vapor must have been escaping also from multitudes of smaller fissures.

On the return by the cars to New Haven, it may be noticed, soon after leaving the station, that there are many low isolated hills of granite-like rock on either side of the railroad, and that a slight sinking of the land would extend the archipelago of the present waters.

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35. To the Peabody Museum.

The Peabody Museum of Yale College is open between the hours of 9 and 6 in summer and 9 and 5 in winter. All rooms that are accessible to visitors have their doors wide open. On the first floor is the collection of minerals and meteorites; on the second, that of fossils; on the third, are the zoological collections; on the fourth, the archæological collections.

On the second floor, in the central part of each room, there are large slabs of red sandstone from the Jura-Trias formation of the Connecticut valley, which are covered with footprints of some of the biped Reptiles (or Reptiles and Birds) that then populated the Connecticut valley; and if the valley, probably also much of the continent. The animals that made them are for the most part referred to the tribe of Dinosaurs by Marsh. One long slab between the cases in the western room is covered with rain-drop impressions; and, in addition, it is crossed by two lines of tracks —one of them of a largish animal that slumped in at each tread, and the other of a small one that left well-defined tracks; and it

may be learned from the slab, by means of the rain-drop impressions, whether the walk of the latter was before or after the rain. Moreover, as the position of the slab is known, it bears a record, in the oblong form of the rain-drop impressions, of the direction of the wind at the time.

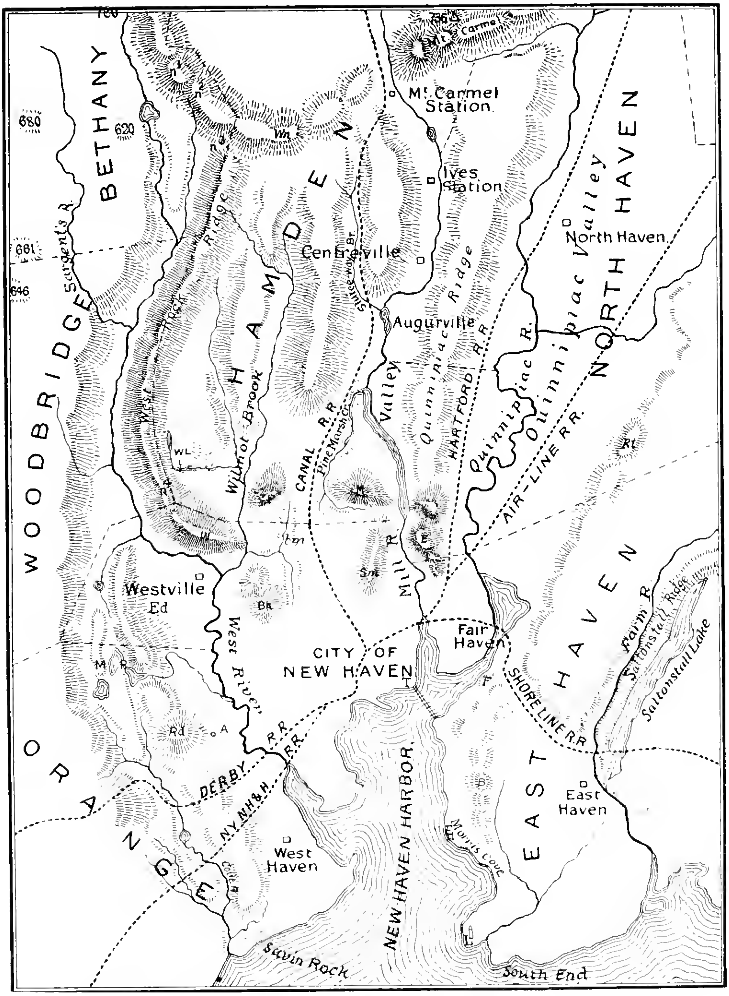
Other smaller specimens of tracks are contained in cases numbered 37 and 38, and some of them show impressions of both the fore and hind feet. The portions of skeletons discovered in the sandstone are not yet in the cases. Some of the slabs are from the Portland quarries, near Middletown, and many from Turner's Falls near Greenfield, Mass. The New Haven sandstone has not afforded any tracks because most of the rock which is quarried here is too coarse to have received such impressions.

There are no specimens of the same species yet known from other parts of the continent outside of the Jura-Trias formation. The bones of some related Dinosaurs from Jurassic beds in the Rocky Mountain region, later in time than those of the Jura-Trias, are to be seen in the western room. Those of one species —Brontosaurus of Marsh—are lying on the floor. Those of another—Stegosaurus of Marsh—are contained in the upright cases numbered 17, 18, against the northern wall; and in the first horizontal case on the right, there are the huge plates and spines with which the middle of its back and tail were armed. But these species of Dinosaurs, unlike those of the Connecticut valley, walked on all fours. The large upright specimen of a Reptile in the center of the room, facing the door, is not Jurassic but belongs to the following Cretaceous or Chalk period, which is not represented in the New Haven region. The species is a Mososaur, of the Genus Holosaurus of Marsh, and is from Kansas. To the same Cretaceous period belong the specimens of a large Kansas bird, which had teeth like a reptile and is named Hesperornis by Marsh, in the first horizontal case to the left of the door.

In the third story, western room, the cases 52–58 inclusive, contain a very full collection of specimens, made by Prof. Verrill of the marine life of the New England coast and the deeper waters outside. All are labelled with names and localities.

These few directions will help those interested to profit by the study of the other labelled specimens in the Museum collections.

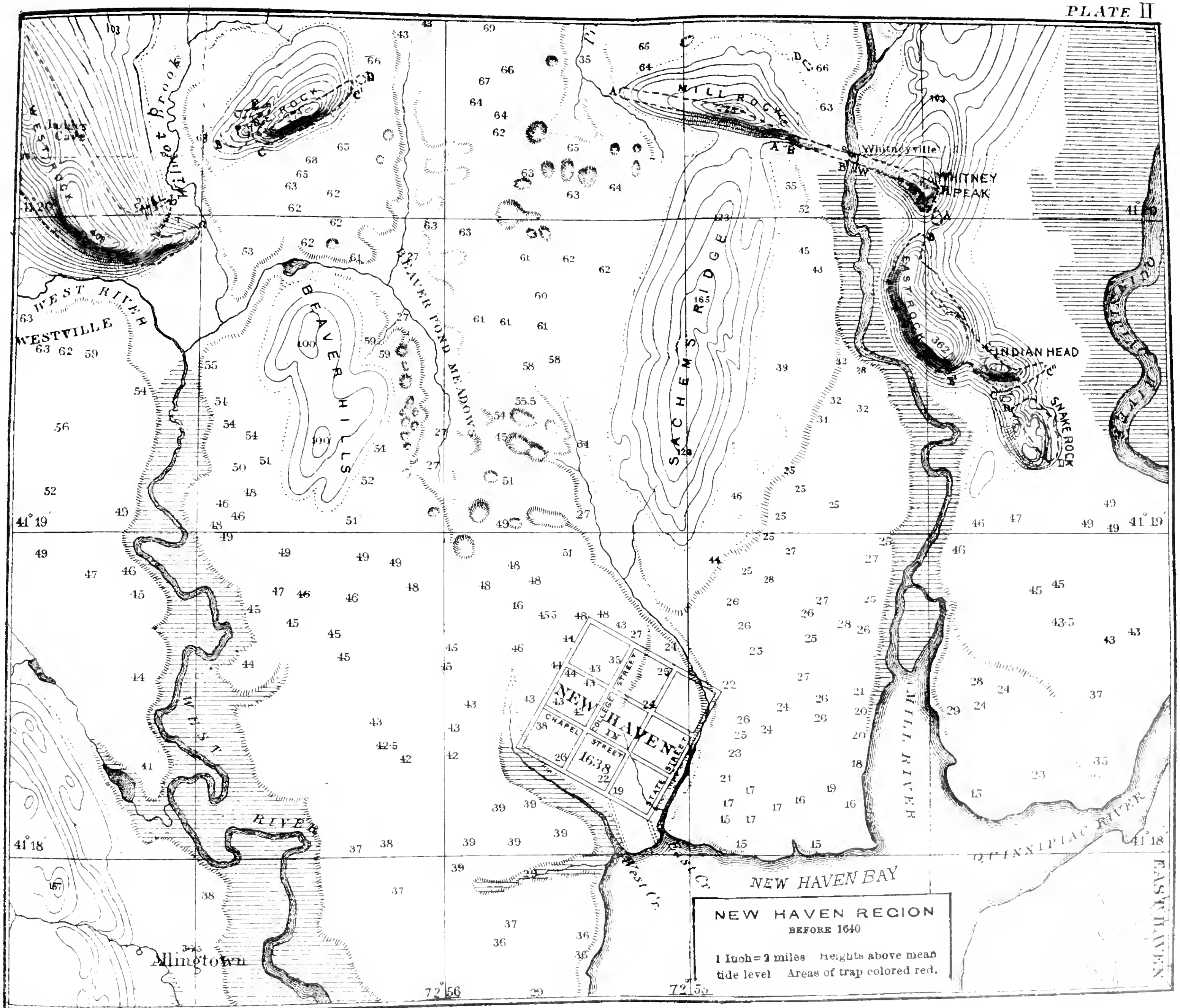
Plate I.

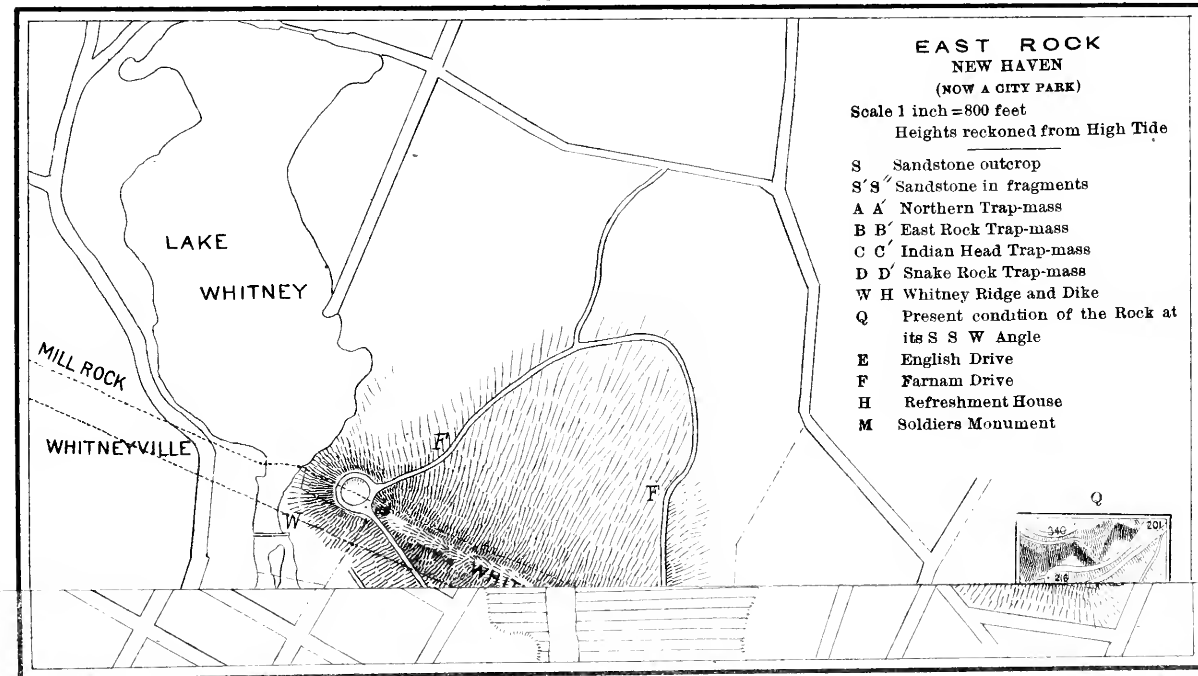


MAP OF THE NEW HAVEN REGION.

Scale $\frac{4}{10}$ inch = 1 mile, or 1 inch = $2\frac{1}{2}$ miles.

Explanations.—A, Allingtown; B, Beacon Hill; Bh, Beaver Hills; E, East Rock; Ed, Edgewood; F, Fort Hale; F′, Ferry Point, or Red Rock, on the Quinnipiac; L, Old Light House; M, Mill Rock; M P, Maltby Park; P, Pine Rock; Rd, Round Hill; Rt, Rabbitt or Peter's Rock; Sm, Sachem's Ridge; T, Tomlinson's bridge, across the head of New Haven Bay; W, West Rock; Wn, Warner's Rock; W L, Wintergreen Lake; *bm*, Beaver Pond Meadows; *f* (below WL) Wintergreen Falls; *n*1, *n*2, *n*3, *n*4, different notches in the West Rock ridge; *n*4, the Wintergreen Notch.


NEW HAVEN REGION
BEFORE 1640
1 Inch = 2 miles Heights above mean tide level Areas of trap colored red.
WEST ROCK
Jacks Cave
Wilmot Brook
MILL ROCK
WEST RIVER
WESTVILLE
BEAVER HILLS
BEAVER POND MEADOWS
SACHEMS RIDGE
Whitneyville
WHITNEY PEAK
EAST ROCK
INDIAN HEAD
SNAKE ROCK
MILL RIVER
QUINNIPIAC RIVER
NEW HAVEN BAY
NEW HAVEN IN 1638
COLLEGE STREET
CHAPEL STREET
STATE STREET
West Cr.
East Cr.
Allingtown
EAST HAVEN
41° 19′
41° 18′
72° 56′
72° 55′


EAST ROCK
NEW HAVEN
(NOW A CITY PARK)
Scale 1 inch = 800 feet
Heights reckoned from High Tide
S Sandstone outcrop
S′ S″ Sandstone in fragments
A A′ Northern Trap-mass
B B′ East Rock Trap-mass
C C′ Indian Head Trap-mass
D D′ Snake Rock Trap-mass
W H Whitney Ridge and Dike
Q Present condition of the Rock at its S S W Angle
E English Drive
F Farnam Drive
H Refreshment House
M Soldiers Monument
LAKE WHITNEY
MILL ROCK
WHITNEYVILLE
W
F
F
Q
340
201
216

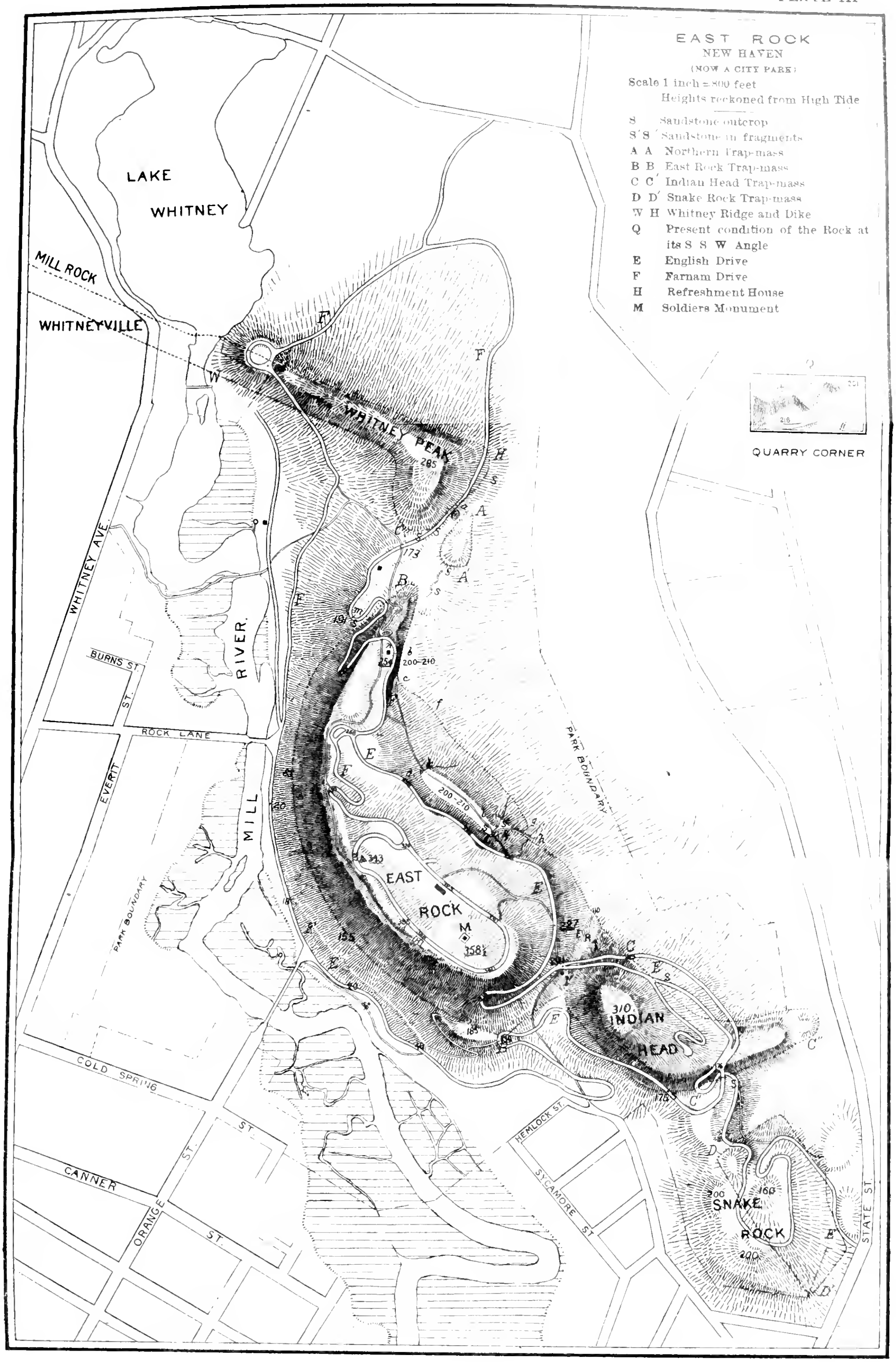
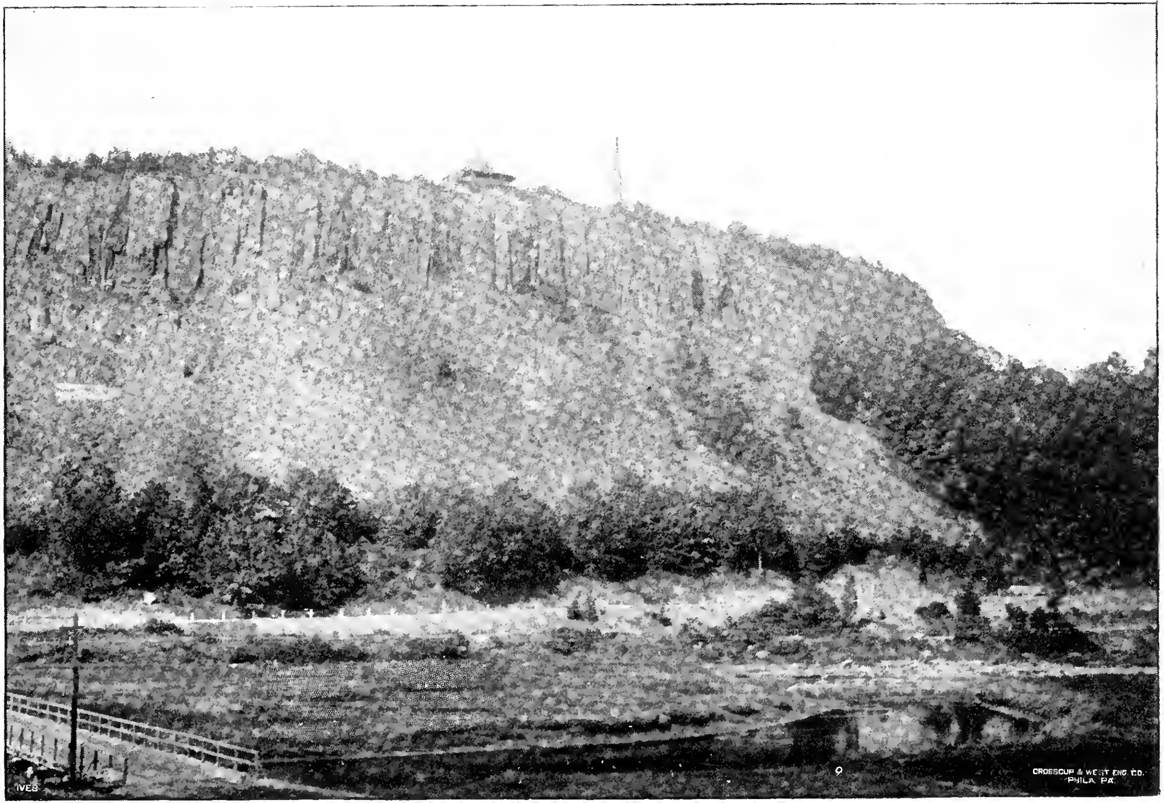
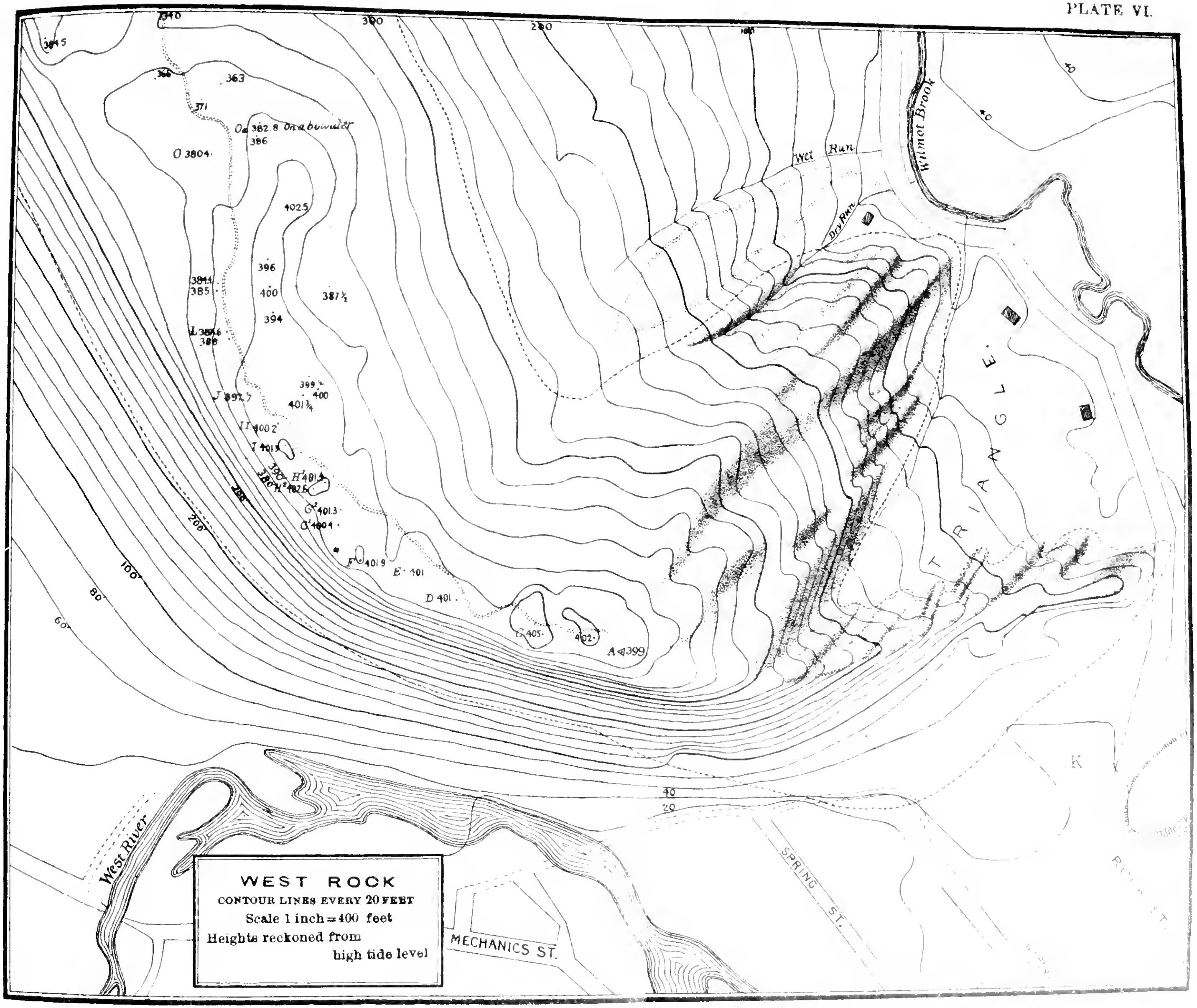

EAST ROCK
NEW HAVEN
(NOW A CITY PARK)
Scale 1 inch = 800 feet
Heights reckoned from High Tide
S Sandstone outcrop
S´S´ Sandstone in fragments
A A Northern Trap-mass
B B East Rock Trap-mass
C C´ Indian Head Trap-mass
D D´ Snake Rock Trap-mass
W H Whitney Ridge and Dike
Q Present condition of the Rock at its S S W Angle
E English Drive
F Farnam Drive
H Refreshment House
M Soldiers Monument
QUARRY CORNER
LAKE WHITNEY
MILL ROCK
WHITNEYVILLE
WHITNEY PEAK
WHITNEY AVE.
BURNS ST.
EVERIT ST.
ROCK LANE
MILL RIVER.
PARK BOUNDARY
EAST ROCK
INDIAN HEAD
SNAKE ROCK
COLD SPRING
CANNER
ORANGE ST.
HEMLOCK ST.
SYCAMORE ST.
STATE ST.

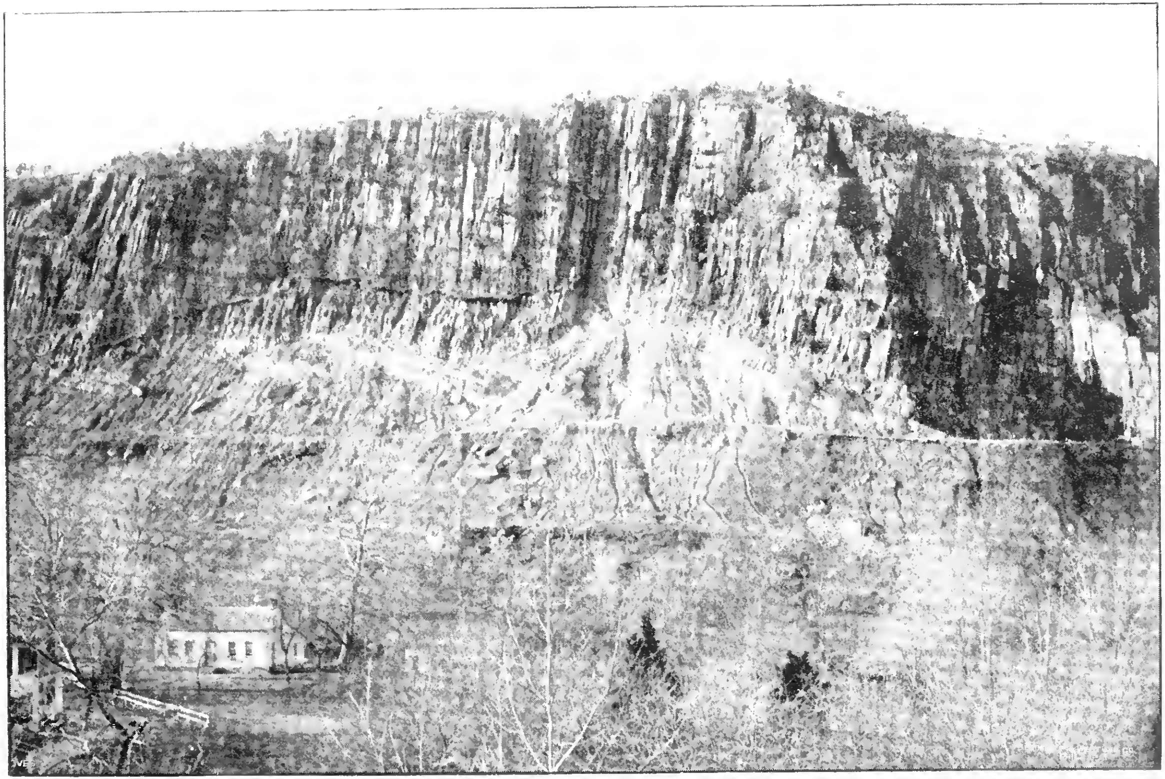
Plate IV.



View of East Rock from the southwest, near Orange Street Bridge.

(From a photograph.)


WEST ROCK
CONTOUR LINES EVERY 20 FEET
Scale 1 inch = 400 feet
Heights reckoned from
high tide level
West River
MECHANICS ST.
SPRING ST.
TRIANGLE
Wilmot Brook
Wet Run
Dry Run
K
300
200
100
80
60
40
20
O 3804
402.5
396
400
394
387½
385
388
401¾
D 401
E 401
A 399



View of the south front of West Rock, showing the trap of the outflow overlying upturned sandstone for a distance of 550 feet.
(From a photograph.)